Commonwealth of Massachusetts
Department of Environmental Quality Engineering
Division of Water Supply and
Office of Planning & Program Management

Groundwater Quality and Protection...

A GUIDE FOR LOCAL OFFICIALS

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DISCLAIMER

This report has been prepared in compliance with Section 208 of the Federal Clean Water Act and has been approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Environmental Protection Agency.

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DEQE's Groundwater Management Project is staffed by the Division of Water Supply. The purpose of the project is to disseminate information about various aspects of groundwater management to the appropriate decision makers in order to protect our existing and potential groundwater supplies.

As a part of this effort, DEQE has prepared a series of six handbooks:

1. <u>Road Salts and Water Supplies: Best Management Practices</u>

2. <u>Underground Water Source Protection in Massachusetts</u>

3. <u>Groundwater Quality and Protection ... A Guide for Local Officials</u>

4. <u>Groundwater Monitoring Handbook</u>

5. <u>Water Supply Protection Atlas Handbook</u>

6. <u>Massachusetts Geologic Information Matrix</u>

A description of each follows:

1. <u>Road Salts and Water Supplies: Best Management Practices</u>

   To prevent further contamination of groundwater sources due to road salts DEQE, in cooperation with the Massachusetts Department of Public Works and the Lower Pioneer Valley Planning Commission, has developed a list of Best Management Practices for road salt use. These address the storage and handling of road salts, their application, and the disposal of salt-laden snow. Recommended practices include preventative, mitigative or restorative techniques. Published in August 1981, this twelve page handbook is being distributed to appropriate state agencies and towns with sodium in municipal water supplies exceeding the 20 mg/l state standard.

2. <u>Underground Water Source Protection in Massachusetts</u>

   This handbook explains the new Underground Water Source Protection Program and the process through which Massachusetts will apply for primacy for the program which will regulate underground injections in the Commonwealth. The twenty page handbook was published in November 1981 and distributed to DEQE personnel and interested general public.

3. <u>Groundwater Quality and Protection ... A Guide for Local Officials</u>

   To assist local officials in managing their groundwaters, this handbook discusses principles of groundwater hydrology, common

contaminants and their sources, and local regulatory and management options. A discussion of groundwater law and a list of federal and state agencies providing groundwater assistance is also included. This handbook will be distributed to all cities and towns and to governmental agencies with groundwater programs.

4. Groundwater Monitoring Handbook

Currently, groundwater monitoring is carried out on a site-by-site basis with responsibilities distributed among several different agencies. This handbook will review existing monitoring programs and current agency responsibilities. Identified information needs will be described, as well as data management needs and monitoring techniques and requirements. Recommendations for monitoring techniques by objective will be included. The handbook will be distributed to agency personnel responsible for groundwater monitoring and also to the interested public.

5. Water Supply Protection Atlas Handbook

The Atlas produced by the DEQE Division of Water Supply contains overlays displaying water supply sources, contamination sites, permitted discharges, aquifers, and drainage basins at the 7½ minute quadrangle scale. This guide presents sources of data and explains in detail the atlas key and numbering system. The guide will be distributed at cost to agencies and persons who purchase the maps.

6. Massachusetts Geologic Information Matrix

The Massachusetts Geologic Information Matrix details all of the currently available sources of information for Massachusetts from the United States Geological Survey on subsurface geology and hydrology. References include: U.S.G.S. geologic quadrangle maps which have been completed as well as those maps in the process of compilation; hydrologic and U.S.G.S. cooperative project bulletins; and miscellaneous U.S.G.S. investigations. Some information on aquifers is also available from town, industry and academic reports.

To receive information on any of these publications, please call:

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Introduction

Groundwater supplies in Massachusetts currently are an important source of the state's industrial, municipal and private water supply. In many areas they also serve as a reserve that can be drawn upon when surface waters become polluted or depleted.

Groundwater reserves are currently threatened by a variety of contaminating sources, such as improperly designed and operated landfills, hazardous waste dumps, the underground storage of fuels, and surface waste impoundments. New cases of groundwater contamination in Massachusetts are being discovered as new sources are explored for drinking water supplies. Since most pollutants in the groundwater move very slowly with the natural groundwater flow, current clean supplies may show signs of contamination years after a polluting practice begins.

Approximately 35% of the Commonwealth's population relies upon groundwater as a drinking water source. Therefore, the frequency and magnitude of these contamination incidents are of concern both to those who manage groundwater withdrawal systems and to city and town administrators who want to understand more about the location and behavior of groundwater and the inevitable association between land use activities and groundwater. Massachusetts is committed to the goal of protecting the quality and quantity of groundwater by working with local governments to protect their groundwater reserves.

This handbook will assist town administrators in making sound judgements about the protection of their groundwater. As a reference and educational source, it presents information on principles, problems and groundwater management techniques.

THE HYDROLOGIC CYCLE

The continuous movement of the water between the ocean, atmosphere and land is called the hydrologic cycle*. As illustrated in Figure 1, the hydrologic cycle is composed of many methods of water movement. The portion of the cycle involving the movement of precipitation from the soil surface through the ground and then into surface waters is of particular importance to an understanding of groundwater.

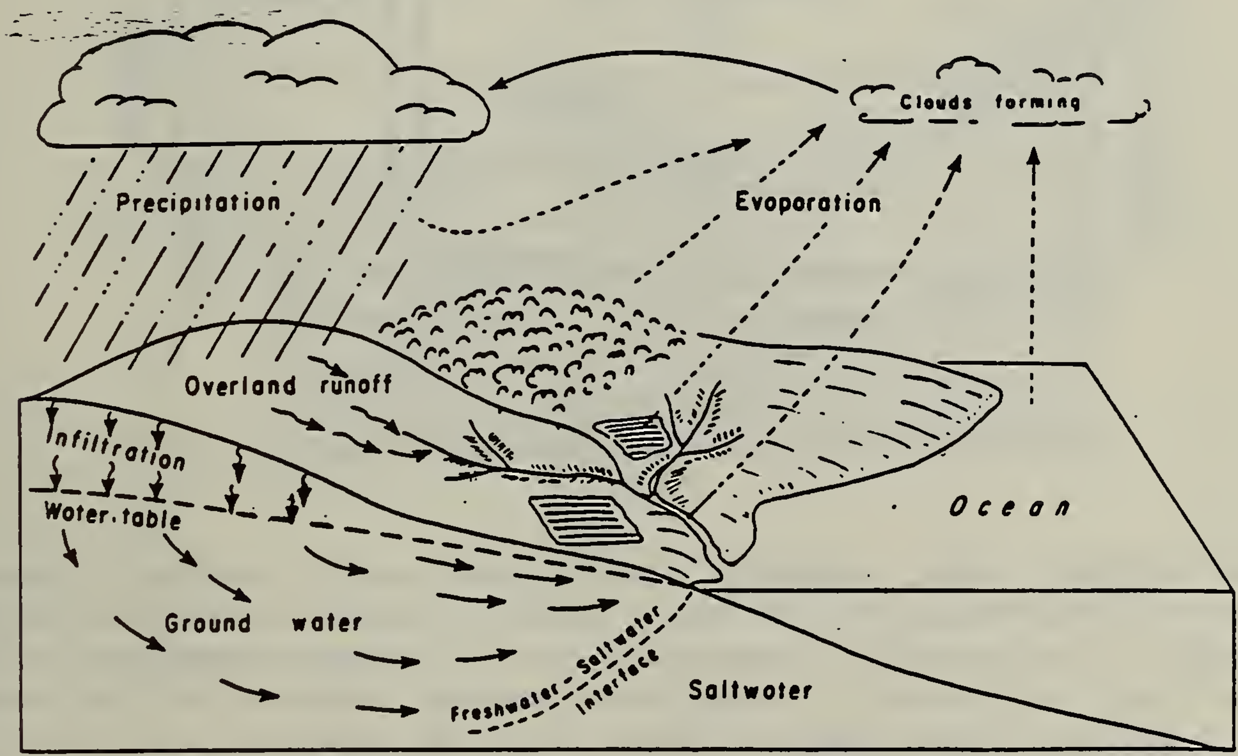

FIGURE 1. Hydrologic Cycle (5)

GROUNDWATER

The term groundwater is applied to the subsurface water that occurs in soil and rock formations that are fully saturated. The importance of groundwater begins at the surface of the earth where water from precipitation infiltrates the soil. A portion of this water moves down through the open spaces (pores or fractures) in soil and rock. The zone in which all the open spaces are filled with water forms the staturated zone. The water level in an open-ended pipe just penetrating the saturated zone is called the water table. Immediately above the water table is a saturated zone where the water is drawn upward by capillary action in much the same manner as water in a thin straw. This area is called the capillary fringe. The capillary fringe in gravel deposits is negligible,

* Terms underlined in Chapter One are defined in the Glossary, Appendix A

but can be as great as five feet in fine-grained sands and clays. All of the water that infiltrates the soil and makes its way to the water table is called recharge. Thus the areas, both on the surface and below, where this recharge occurs (areas of maximum infiltration), are of key importance to protecting the groundwater resource.

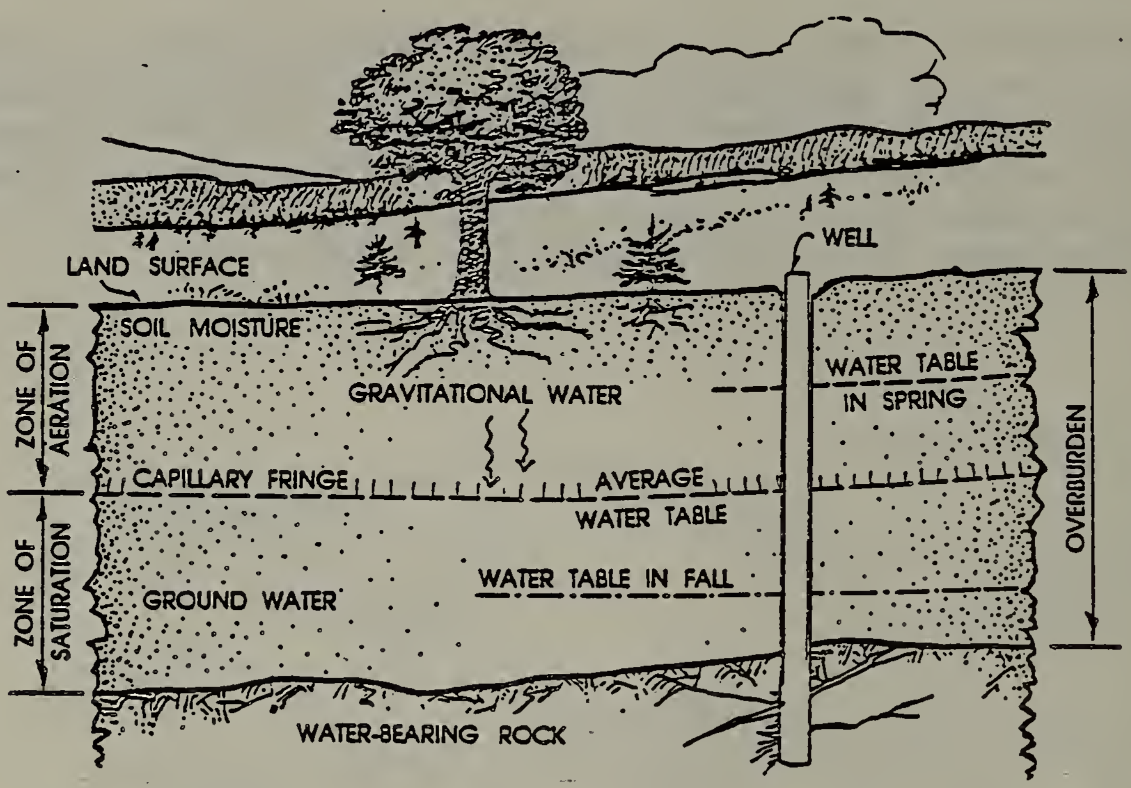

FIGURE 2. Divisions of Subsurface Water (2)

For the most part, recharge areas permit water to move downward to the zone of saturation and the water table, forming a water table aquifer (Figure 3A). Occasionally however, layers of nearly impermeable materials (such as clay) may greatly retard the downward movement of the water forming a perched water table (Figure 3C). In other cases, the upward movement of the groundwater may be greatly reduced by a confining layer. The water beneath this layer becomes confined and an artesian system can develop. In an artesian system the groundwater is under pressure, which allows for the development of flowing artesian wells drilled into this layer (Figure 3B).

GROUNDWATER STORAGE YIELD

The amount of water that can be stored and extracted from the ground depends upon a number of factors. A few of the major factors will be briefly discussed. For a more thorough review, the reference section provides a number of excellent publications on this subject.

The porosity of the subsurface material is an important determinant of the amount of water held in the ground. The porosity of rock and loosely packed or unconsolidated material is defined as the percentage of pore spaces in the total volume. It is calculated by dividing the volume of the pore spaces by the total volume (whether saturated or not)

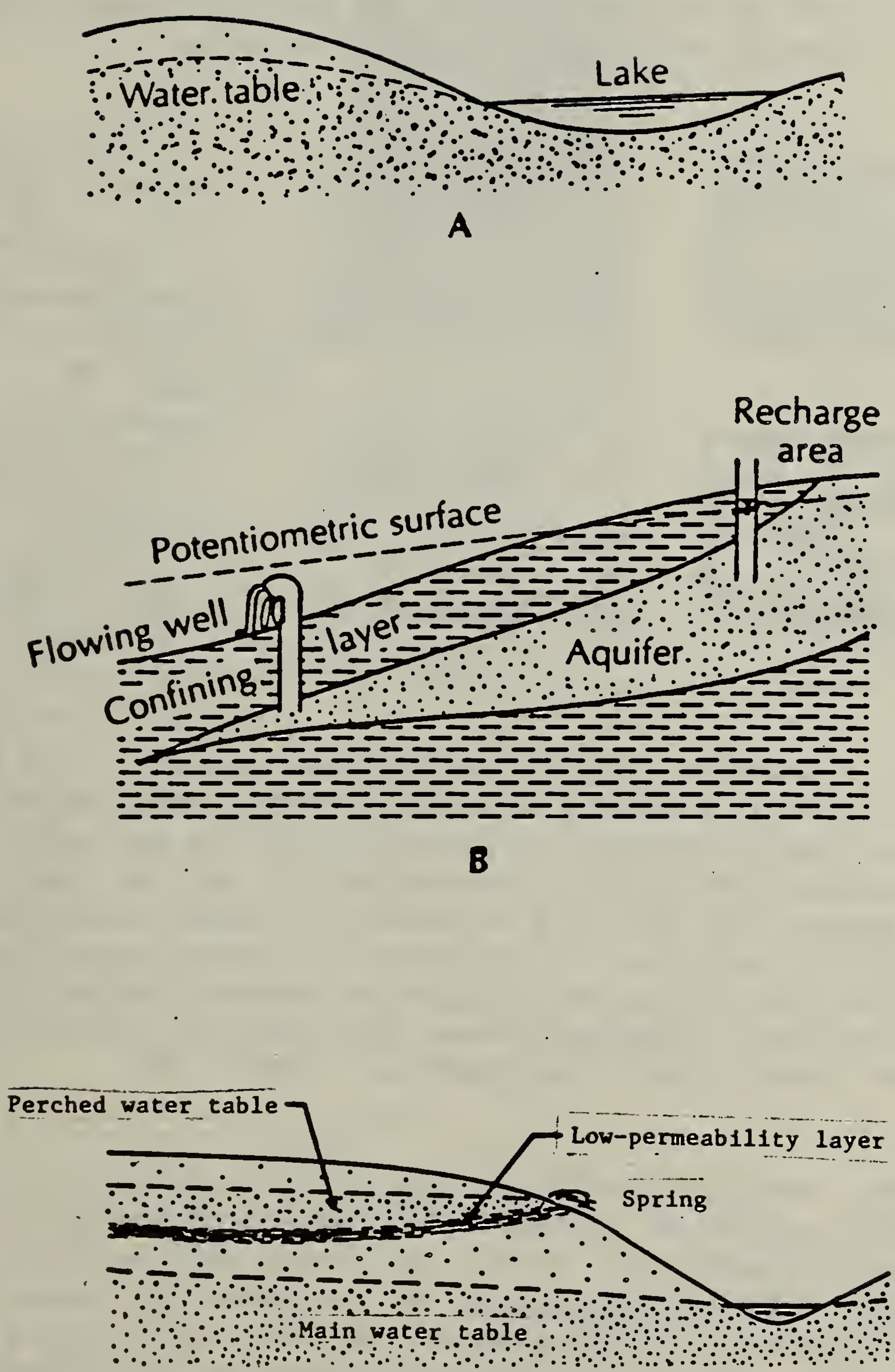

FIGURE 3. A. Water-table Aquifer;
B. Confined Aquifer;
C. Perched Aquifer.

All figures are vertically exaggerated to show the slope of the water table (3).

of the material and then multiplying by 100. A typical porosity value for clay would fall between 45-55%, while a gravel would have a value from 20-35%. It is the shape, arrangement, and sorting of the particles which determines the porosity of a material (Figures 4). The greater the porosity, the greater the amount of water a saturated material can hold. However, not all of this water can be considered available for withdrawal or movement within the hydrologic cycle.

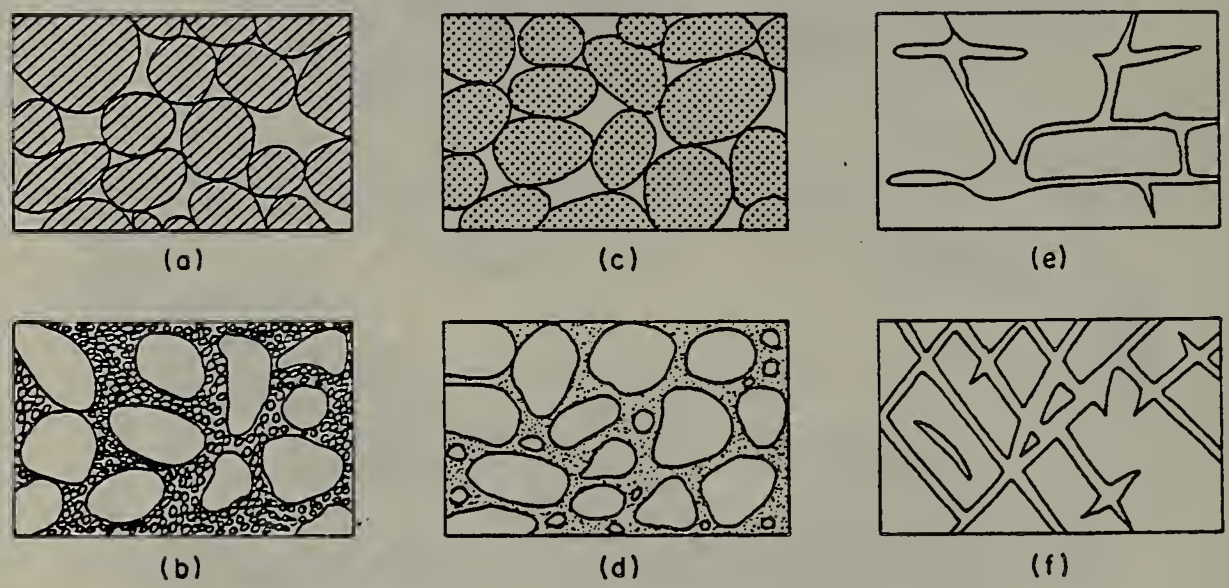

FIGURE 4. Relation between texture and porosity: (a) Well-sorted (uniform sizes) sedimentary deposit having high porosity; (b) poorly sorted sedimentary deposit having low porosity; (c) well-sorted sedimentary deposit consisting of pebbles that are themselves porous, so that the deposit as a whole has a very high porosity; (d) well-sorted sedimentary deposit whose porosity has been diminished by the deposition of mineral matter in the pore spaces; (e) rock rendered porous by solution; (f) rock rendered porous by fracturing (after Meinzer, 1923). (4)

Two terms, specific yield and specific retention, are important to understanding groundwater systems. The amount of water that drains, i.e., what can be extracted, from a saturated soil or rock is called the <u>specific yield</u>. <u>Specific retention</u> is the amount of water that a saturated soil or rock will retain against the force of gravity if it is drained. Specific retention (otherwise known as field capacity) is expressed as a percentage of the total volume of the saturated material. The specific retention is high for fine-grained materials and low for coarse sands and gravel. Together, the sum of the specific yield and the specific retention equal the porosity of soil or rock. Figures 5 and 6 show the relationship of these three terms for various types of material. For example, coarse sand has a specific retention of 7% and a specific yield of 32%; these add to equal the porosity at 39%.

It is the specific yield and not the porosity which determines the amount of groundwater available for withdrawal. For the most part,

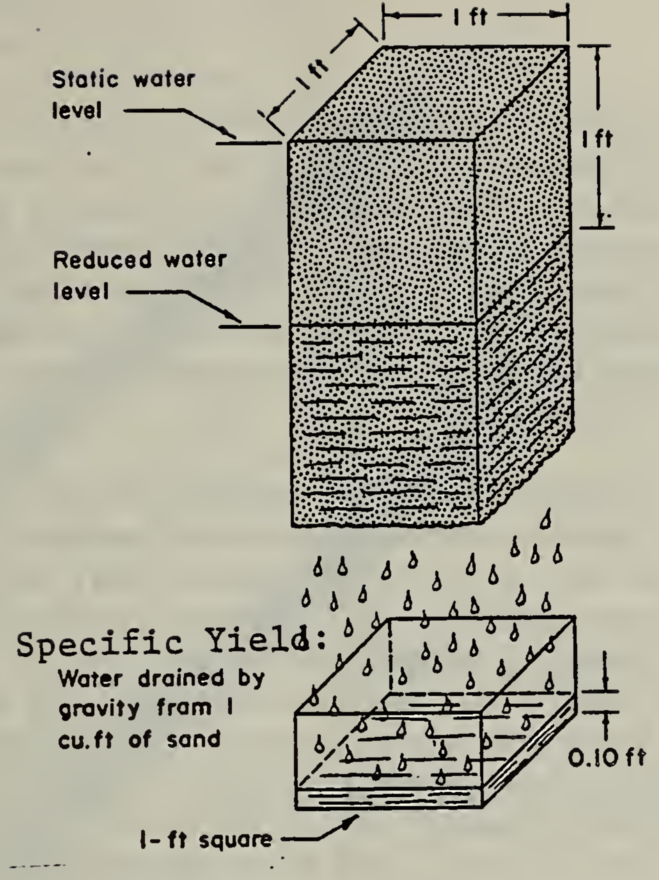

FIGURE 5. Specific yield of sand can be visualized from this diagram. Its value here is 0.10 cu. ft. per cu. ft. of aquifer material (5). Expressed as a percentage is would be 10%.

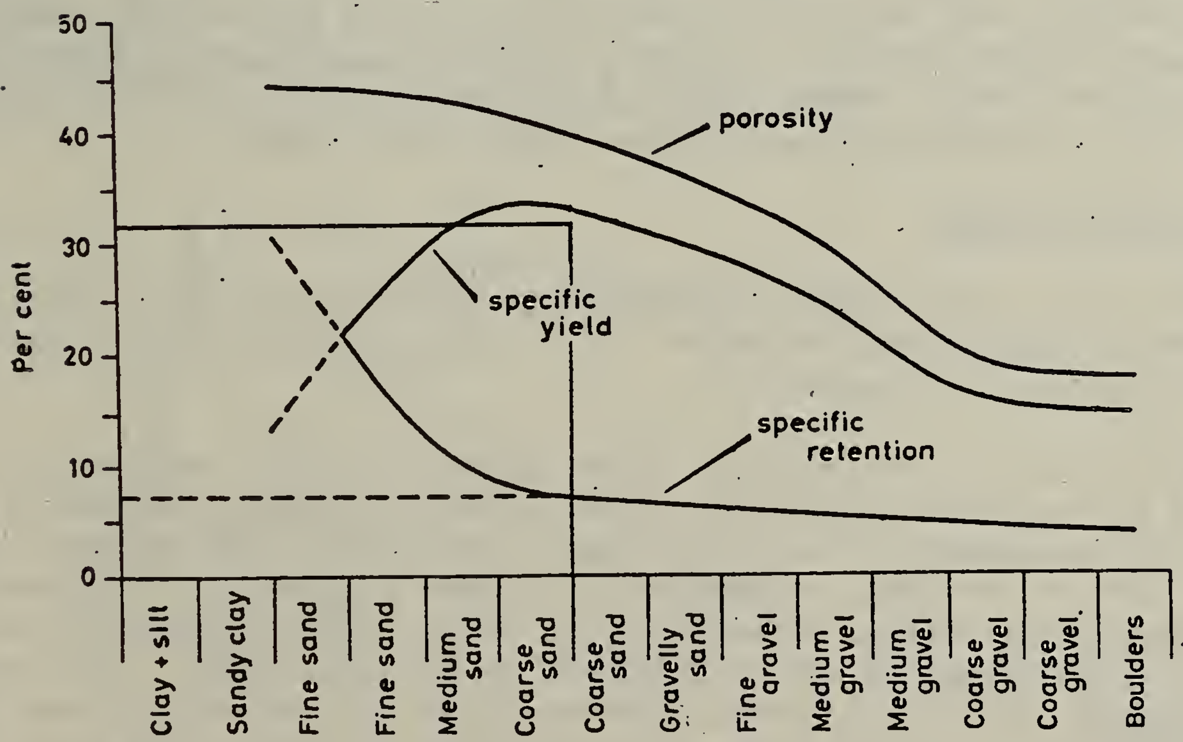

FIGURE 6. Diagram showing the relationship between specific retention, specific yield, and porosity for different types of material. (From an original diagram by Eckis (40).) (6)

coarse textured materials with large pore sizes (such as sand and gravel) permit more water to pass through than do finer textured materials (such as clays). Although the porosity of the clay is much greater than that of the gravel, the small pore spaces are so small that the tensional forces hold the water much more tightly and the specific yield is lower. While the specific yield will estimate the volume of water that can drain from porous materials, it is the permeability which indicates how fast the water will drain.

A French engineer, Henry Darcy, determined in the mid-nineteenth century that the flow of water through a porous medium is proportional to the hydraulic gradient and inversely proportional to the flow path. He also determined that the quantity of flow was porportional to a coefficient, K, dependent upon the physical properties of the porous medium. The result is an empirical expression known as Darcy's Law (see Figure 7). The standard term now used to measure flow resistance of earth materials is hydraulic conductivity (K). The hydraulic conductivity is a function of the properties of both the fluid and the material through which the fluid flows. The term intrinsic permeability (k) has been defined as a property of the porous medium only, neglecting the fluid properties of viscosity and density. Figure 8 provides ranges of values associated with the common earth materials for the hydraulic conductivity of water.

For rough estimates of yield from an aquifer the concept of transmissivity (T) is often used. This is determined by multiplying the hydraulic conductivity by the thickness of the saturated zone. The units are distance squared per time such as gallons per day per foot or square meters per day. This concept assumes that the flow through the aquifer is horizontal which may or may not be valid (see Figure 7). The USGS hydrologic atlases use this parameter. It can generally indicate the best areas for future water supplies; however, site specific testing and analyses are necessary to determine local conditions.

GROUNDWATER MOVEMENT

The general circulatory movement of water within the hydrologic cycle has already been discussed. This section will briefly describe the principles (see Figure 2).

Water, once in the ground, flows under the force of gravity. Recharge areas, such as hilltop areas and side slopes, are where water enters the groundwater flow system and subsequently discharges to areas such as rivers, streams, swamps or the ocean. Ideally, to determine the direction of groundwater movement, the water table elevation and the vertical flow potential are determined at several places. The wells (piezometers) used to determine the vertical flow potential are open to the groundwater only for a short distance at the end. The best way to conceptualize the dynamic movement of groundwater is through a diagram (Figure 9). In order to achieve this ideal flow condition the material must be of uniform texture (homogeneous) and be equally permeable in all directions (isotropic). Nature is not normally as orderly as this; however, generalizations may be made to approximate groundwater movement and more easily understand its flow paths. In most cases, the water

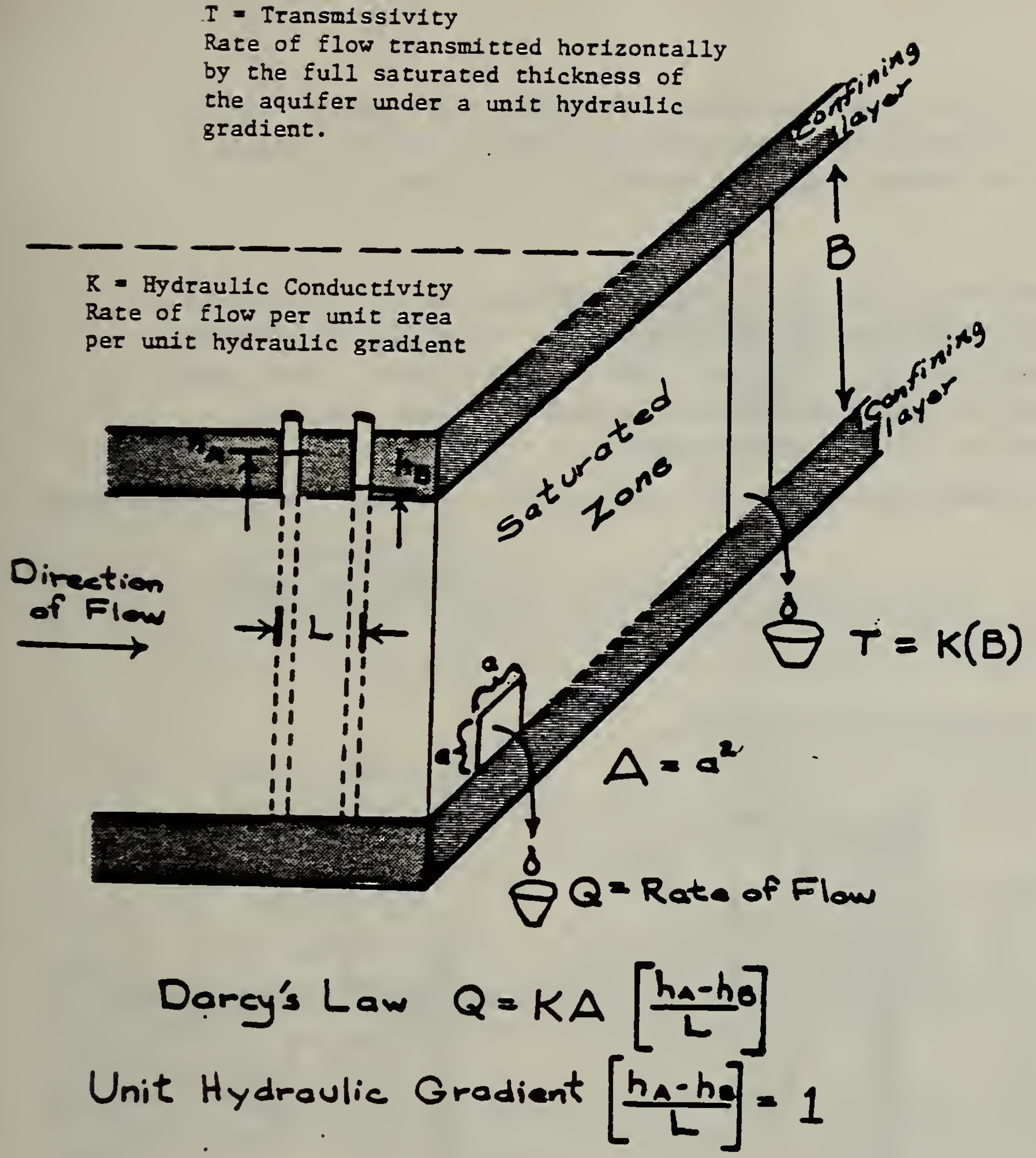

FIGURE 7

Hydraulic Conductivity and Transmissivity.

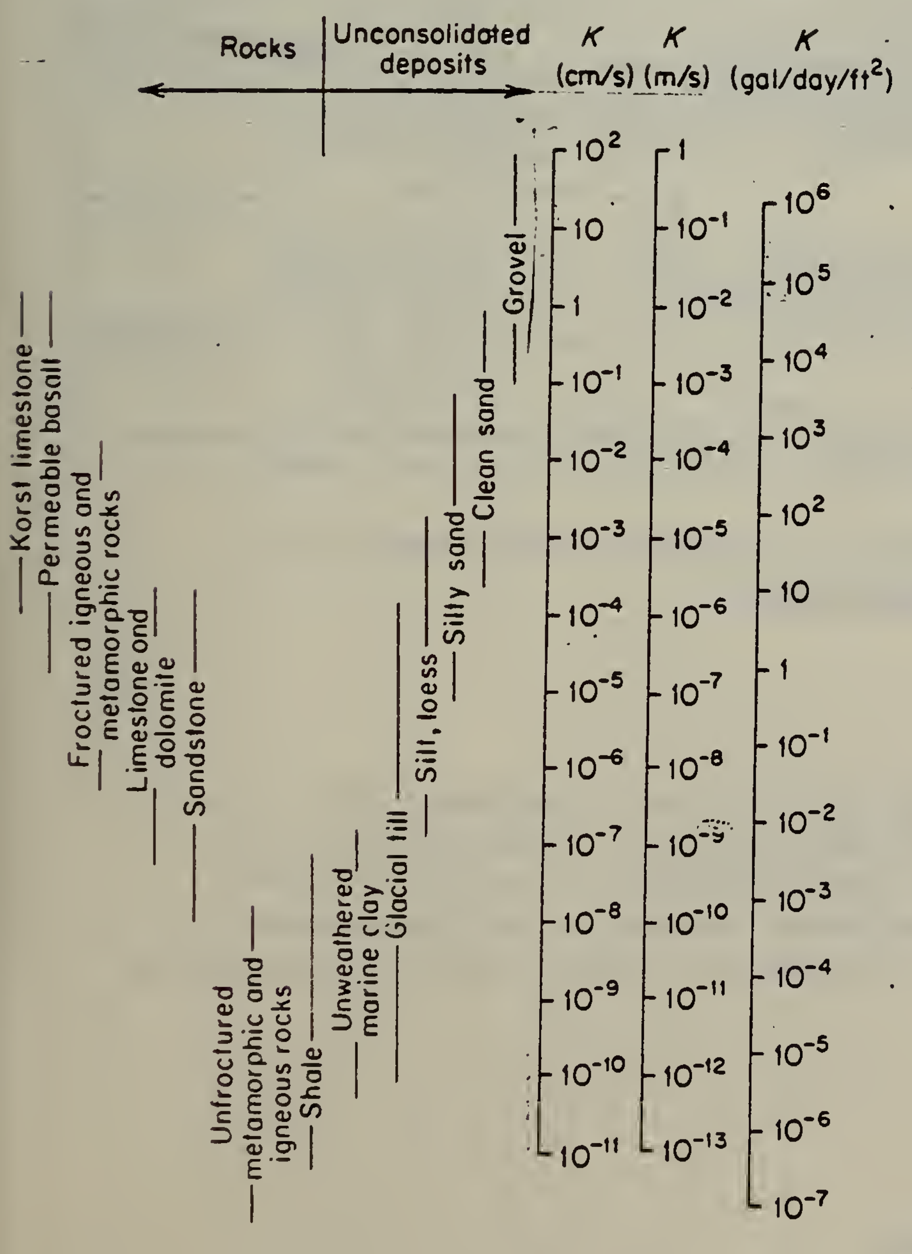

FIGURE 8

Ranges of Values of the Hydraulic Conductivity of Water (K) (4).

table is nearly parallel to the land surface; however, the water table is usually not as steep. This allows the general direction of groundwater flow to be inferred by examining the surficial slopes on a topographic map.

Recharge to the groundwater is not always limited to upland areas. Streams and ponds may contribute to the groundwater, especially during high surface water flow and low groundwater table conditions. Wetlands which are underlain by relatively impermeable materials may impound water that slowly recharges a lower water table.

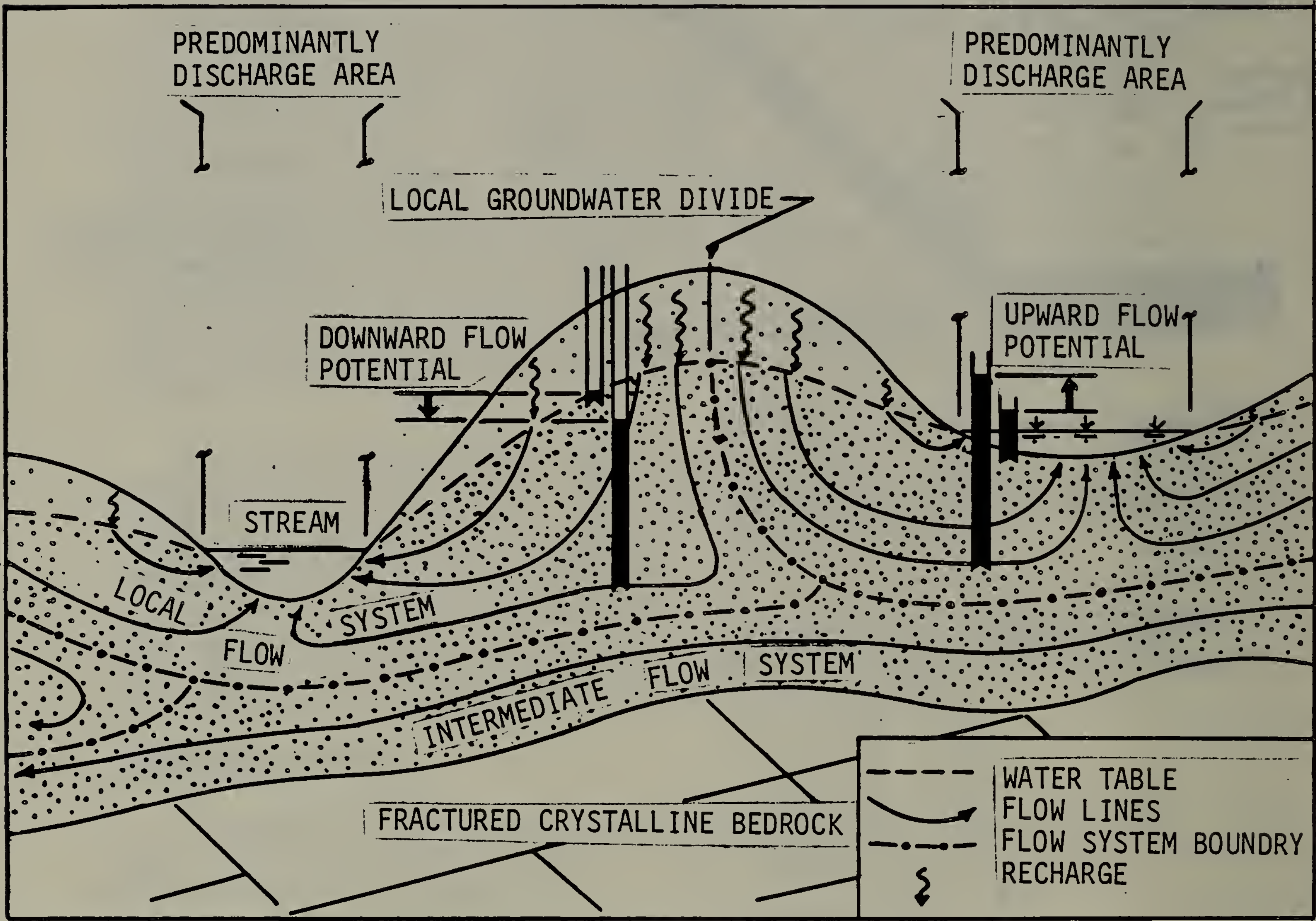

FIGURE 9. Groundwater flow systems in unconsolidated materials (1). Vertical scale exaggerated.

Conclusions

Groundwater is one of the key elements in the hydrologic cycle. The principles of groundwater movement and the physical characteristics of aquifers form the basis to develop an understanding of related issues. The evaluation and protection of groundwater resources and the study of contamination incidents are areas of increasing interest where hydrogeology is applied.

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CHAPTER TWO: COMMON CONTAMINANTS AND SOURCES

2A. Types of Pollutants Found in Massachusetts Groundwater

Experience has shown that certain contaminants present the most common problems to Massachusetts communities in their charge to maintain a clean, safe, public drinking water supply.

The U.S. EPA has published guidelines and regulations in the Federal Register for various contaminants under both the Safe Drinking Water Act and the Clean Water Act. The EPA Office of Water Supply has National Primary Drinking Water Regulations for nine inorganic chemicals, seven organic chemicals (including total trihalomethanes), turbidity, coliform bacteria and radionuclides (the Massachusetts DEQE Division of Water Supply also has regulations for dissolved oxygen (D.O.) and biochemical oxygen demand (B.O.D.)). Appendix D has a list of all the primary drinking water standards for Massachusetts public drinking water supplies.

EPA's National Secondary Drinking Water Regulations address 12 contaminants and are concerned with taste, odor, and color; i.e., more "aesthetic" concerns. EPA also has SNARLS (Suggested No Adverse Response Levels) for seven compounds with possible toxic effects and another fifteen compounds in the "draft" or "opinions" stage. These SNARLS are not nationally enforced, but the Massachusetts DEQE Division of Water Supply uses them for guidance in chemical contamination incidents. Since the SNARLS are not legally enforceable, states can be more stringent and DEQE has recommended a stricter SNARL for 1,1,1-trichloroethane of 1.0 ppm.

The EPA Office of Water Quality has also published concentration guidelines for 65 of the 129 priority organic chemicals in the Federal Register. These guidelines are established under the Clean Water Act and thus are concerned with aquatic life, fisheries, water contact recreation and aesthetics, in addition to drinking water concerns. Thus, they are determined by different criteria than those for water supply and, accordingly, some contaminants have different "maximum contaminant levels" in the two regulations.

This handbook has selected for review some of the more common contaminants found in Massachusetts public water supplies. A discussion of each potential contaminant, its natural and man-made sources, its health and environmental impacts and the recommended or required drinking water standards for the selected contaminants follows:

- 2A.1 Metals: Sodium, Iron, Manganese and Arsenic (a metalloid)
- 2A.2 Nitrates
- 2A.3 Petroleum Products: Oil and Grease, PCBs
- 2A.4 Pesticides
- 2A.5 Other Organic Compounds: TCE, 1,1,1-Trichloroethane, Chloroform, and Cyanide
- 2A.6 Radioactive Sources

2A.1 Metals

Metals commonly tested for in water supplies include sodium, iron, manganese and a metalloid, arsenic. A discussion of each one's natural and man-made sources, the health effects of excessive intake, and each one's water supply standards follows.

Sodium

Sodium ions in groundwater come from both natural and man-made processes. Leached salts from surface deposits, rain containing evaporated ocean spray, and saltwater entering coastal aquifers are some natural salt sources. Inputs from human activities include runoff from the storage and use of deicing chemicals and the leaching salts from septic systems. In addition, sodium hydroxide and similar products are frequently added during water treatment for corrosion control in older distribution systems (1).

When present in large amounts, sodium in drinking water can pose a health hazard. Documented research has shown that excessive sodium intake is correlated with high blood pressure, with approximately 15 to 20 percent of the population at risk of developing hypertension (2). Also, some British studies have implicated sodium in the phenomenon of crib death (1). Limited sodium intake is recommended for individuals with cardiovascular diseases, renal (kidney) and liver problems, and metabolic disorders (2).

Healthy individuals are able to maintain the body's sodium balance at an intake of 2,000 milligrams per day (mg/day) or less; however, a small segment of the population is restricted to levels of 500 mg/day (4).

Typically, sodium in drinking water represents less than 10% of the total daily intake of adults. However, those on restricted diets are generally limited to 500 mg/day. Intake from food cannot feasibly be reduced to less than about 440 mg per day.

Massachusetts has established a maximum contamination level of 20 milligrams per liter (mg/l or ppm) for sodium ion in public water plies. If this level is exceeded, the state and all users must be notified so that any "at risk" people may adjust their water consumption.

In 1980, 47 Massachusetts communities exceeded the 20 ppm standard (5). The majority of these communities are served by groundwater sources. Other studies have also shown increasing sodium concentrations in water supplies, a trend attributed to the use of deicing and water softening chemicals (4). This evidence shows that protection of groundwater supplies from sodium contamination is needed.

Iron

Iron, one of the most abundant elements in the earth's crust, is a natural constituent of groundwater systems. High amounts of iron may be found under naturally acidic or reducing conditions. Three natural conditions that have been found to produce high levels of iron in groundwater are:

1) aquifers located over crystalline bedrock;
2) swamps; and
3) organic material, interbedded with alluvial and glacial sediments located near areas of groundwater discharge (8).

Iron is also present in the environment due to man's activities. Indusial wastes and mine drainage waters are two common sources.

Iron is an essential trace element, vital for oxygen transport in the blood of all vertebrates and some invertebrates. The daily nutritional requirement for iron is 1 to 2 mg, but the intake of larger quantities is needed due to poor absorption (9).

The main problems attributed to excessive iron concentrations are the staining of laundry and porcelain, and its undesirable taste in water. At concentrations above 0.3 mg/l staining occurs and a bitter sweet, astringent taste may be noticeable (8). Although the use of water containing this level of iron is allowed, aesthetically it is undesirable.

In Massachusetts, much of the groundwater contains concentrations which exceed the recommended limits of iron. In the past these supplies were bypassed and other less contaminated aquifers were used. However, current water shortages are causing these supplies to be considered for future use, thereby increasing the need for treatment of iron-bearing waters (8).

Manganese

Manganese is commonly found in salts and minerals. Often it is associated with iron which has several similar characteristics. However, the quantity of manganese found in the earth's crust is much less than the amount of iron (6).

Manganese is used mainly in metal alloys, dry cell batteries, lime and micro-nutrient fertilizers, paints, and in chemical reagents such as permanganates. Manganese is vital to both plants and animals as a micronutrient. A deficiency of manganese in plants may result in chlorosis, a yellowing of the leaves.

The incidence of manganese toxicity is rare because manganese is rapidly excreted in the kidney (42). The primary concerns with manganese contamination deal with aesthetics. Levels above 0.05 mg/l cause problems similar to those encountered with iron - the development of a brown color which stains laundry, and an undesirable taste and thus EPA's secondary maximum contaminant level of 0.05 mg/l should ensure that these characteristics will not be present (6). This level is frequently exceeded in Massachusetts.

Arsenic

Metallic arsenic is a shiny, brittle, grey element which is ubiquitous in nature and nearly insoluble in water. The metallic form is only slightly toxic; however, some compounds containing arsenic, found naturally in soils, are known to cause subacute and chronic arsenic poisoning in humans (10).

Our use of these compounds has increased the concentrations found in water. The industrial processes employing arsenic are diverse.

nemia developed following the ingestion of untreated well water having a high nitrate content.

Nitrate contamination is common in shallow farm and rural community wells where protection against leachate from barnyards, fertilized fields, and septic tanks is minimal (6). EPA has determined that water containing less than 10 mg/l NO_3^- as nitrogen is safe for infant ingestion, and Massachusetts has established this as the maximum contaminant level for nitrate in public water supplies.

2A.4 Petroleum Products

Petroleum-related products include oil, grease, and the oil additive, PCB. A discussion of the natural and man-made sources of each, the recommended concentrations in drinking water and the effects of pollution follow.

Oil, Grease and Gasoline

Oil, grease and gasoline are three petroleum products. They enter water systems through accidental spills, leaks in underground storage tanks, and improper disposal practices. They contain thousands of organic compounds with diverse physical, chemical and toxicological properties with equally diverse environmental impacts (6).

Water contaminated with petroleum products has a foul taste, even when only small concentrations of these substances are present. The taste and coloring of the contaminated water would be too obnoxious to drink before concentrations of these petroleum products reached toxic levels for humans. Unfortunately, man is still exposed to these dangerous substances when he consumes aquatic organisms which come from waters contaminated by these petroleum products. The group of polycyclic aromatics, a carcinogen found in petroleum products, is accumulated in the tissues of aquatic organisms which are subsequently consumed by man.

These products float in water and thus can contaminate surface waters where the water table meets the surface. When large quantities of oil and grease enter surface waters, fish kills, due to their gills being coated, are common. Also, oil and grease can coat the feathers of water fowl, often resulting in their death. To protect wildlife and the aesthetic qualities of water, EPA recommends that surface waters be virtually free from these substances.

Polychlorinated Biphenyls

From 1929 until the late 1970s polychlorinated biphenyls (PCBs) have been manufactured in this country. A group of hydrocarbons closely resembling DDT, PCBs are extremely stable biologically and chemically.

Although their use is no longer allowed, previously produced PCBs are still being used today in many industrial processes due to their heat exchange and dieletric (non-conducting) properties (6). They were primarily used in electrical transformers and capacitators as insulating fluids, in heat transfer and hydraulic systems, and as plasticizers (1).

The health and environmental hazards associated with PCBs were

first discovered in Japan in 1968 when fish were found to be contaminated. Human consumption of fish and frogs from waters containing PCBs can result in skin, liver, and kidney lesions, swelling of the eyelids, nerve damage and cancerous growth (6).

Unfortunately, prohibiting the production and use of PCBs has not solved the problem. Waters already contaminated continue to be a health hazard due to the persistence of PCBs. The Housatonic River was contaminated with PCBs from a nearby company. PCBs leached into groundwater supplies from improperly disposed waste oil (1), and now a large clean-up program will be required to remove the contamination. Protecting ground- and surface waters from contamination can eliminate the need for these difficult clean-up programs.

2A.5 Pesticides (Insecticides, Herbicides and Rodenticides)

Pesticides are chemical compounds used to control unwanted organisms such as fungi, bacteria, weeds, insects, and rodents. These compounds differ according to their target organisms, chemical nature, physical characteristics, and mode of action. Thus, their effects on the environment also vary greatly (10).

Pesticides enter ground and surface waters in several ways. Insecticides and herbicides may be used on aquatic insects and plants; runoff and percolating rainfall can pick up and transport pesticides; wastewater from manufacturing processes may accidentally or deliberately be discharged; drift of pesticides occurs during application on agricultural lands; and cleaning the application equipment can also add to the pollutant load (8).

When pesticides enter water, through leachate and runoff, ingestion can cause severe effects. Almost all the pesticides being used today can be fatal to humans if they are ingested in sufficient quantities. However, their degree of toxicity varies (10). The quantity of pesticide which is a health threat tends to be very small. Even concentrations of parts per billion can make a drastic difference in the toxicity.

For some compounds, various effects have been observed. For instance, four agricultural workers became impotent after prolonged exposure to several types of pesticide. Often short-term effects do not develop, yet serious problems may occur in future years. Research has shown that some pesticides induce cancerous growth, mutations, and congenital defects (10).

Pesticides should be carefully chosen and cautiously applied in order to minimize these potential adverse effects.

2A.6 Other Organic Compounds

Other organic compounds of concern in drinking water supplies in Massachusetts include trichloroethylene (TCE), methyl chloroform (1,1,1 trichloroethane) and chloroform. A discussion of each follows.

Trichlorethylene

Trichloroethylene (TCE) is a chlorinated organic compound. Not naturally present in groundwater, its relative insolubility in water combined with its greater density causes it to sink to the bottom of the groundwater column. Normally, this would not be a problem except that TCE is not readily biodegradable (7).

TCE is primarily used as an industrial solvent for degreasing metal and cleaning electrical parts. It has also been frequently used as a solvent in dry cleaning practices since the 1930s. Major sources of contamination include the above uses, the cleaning of septic systems, and illegal disposal practices (7).

The toxic effects of TCE can be severe. Cancer has been found in laboratory mice after exposure, and thus it is a suspected human carcinogen. TCE can enter the body in three ways - from ingestion, inhalation, and through the skin. Once it enters the system it travels to the bloodstream and eventually can cause severe liver and kidney damage. Edema of the lungs is also common. In order to protect individuals from excess cancer risk, a maximum contamination level of 4.5 parts per billion (ppb) has been recommended by the Environmental Protection Agency (7).

Methyl Chloroform

Methyl chloroform (1,1,1 trichloroethane) is similar in properties to TCE; however, its toxicity is not as great. Like TCE, methyl chloroform is used as an industrial metal degreaser and an electrical parts cleaner. Its solubility in water is low and degradation is not rapid (7).

Ingestion of methyl chloroform affects the central nervous system where it acts as a depressant, and the kidneys and liver are slightly affected at high concentrations (7). At this time there is no evidence that methyl chloroform is a carcinogen, but further research is needed to determine the long-term effects. The National Institute of Occupational Safety and Health (NIOSH) recommends that the maximum level of methyl chloroform in drinking water be set at 33 ppb in order to protect individuals from the effects of short-term exposure (7). EPA has established 1 mg/l long-term as its SNARL (Suggested No Adverse Reaction Level) (42) and Massachusetts DEQE may recommend a stricter limit.

Chloroform

Chloroform, a member of the trihalomethane (THM) family, is the most common trihalomethane found in drinking water supplies. The major source of chloroform and other trihalomethanes in drinking water is the mixing and reaction of chlorine added for disinfection with the common and nontoxic organic substances produced by natural decomposition or by the metabolism of aquatic animals and plants. Since these natural organic compounds are more commonly found in surface water, drinking water from surface sources is more likely to produce high levels of THM (12).

Chloroform is a highly toxic compound that is readily absorbed and metabolized in the human system. It affects the central nervous system and has been confirmed as a carcinogen in animals. The effect from long-term human exposure at low concentrations is a serious concern of the Environmental Protection Agency. EPA has established a maximum contaminant level of 0.10 mg/l (PPM) for the combined total of the concentrations of all THM compounds.

THM compounds can be controlled in drinking water in the following ways:

1) Use of a disinfectant that does not generate THM in water.
2) Treatment to reduce the natural organic chemical concentrations prior to chlorination.
3) Various treatments to reduce THM concentrations after formation. The use of granular activated carbon (GAC) is the most commonly proposed method (12).

Cyanide

Cyanide is one of the simplest and most reactive organic complexes commonly found in nature. As a radical, it combines easily with many ions. The most common compounds formed are hydrocyanic acid (HCN) and alkali metal salts such as potassium cyanide (KCN) and sodium cyanide (NaCN). The persistence of cyanide in water varies with the chemical form of the cyanide, its concentration, and the other constituents present (6).

Cyanide may enter water systems in the discharge from manufacturing processes. Also, plants and animals produce cyanide as metabolic intermediates. The cyanide is excreted by these organisms since they do not usually store the intermediate for any length of time (6).

Hydrocyanic acid is the most toxic form of cyanide; however, many other forms also have negative effects. Cyanide readily moves into the blood where it travels in the plasma. Reactions which occur in the bloodstream inhibit oxygen metabolism by decreasing the oxygen exchange capacity of the body tissues (6).

In humans, large quantities must be ingested in order to cause severe health problems. Cyanide in water is lethal to humans when the concentration ingested in water exceeds the detoxifying abilities of the body (6). To ensure safety from these effects, the U.S. Public Health Service recommends an objective of 0.01 mg/l in drinking water, but has set 0.2 mg/l as the maximum permissible limit (6,8).

2A.7 Radioactive Sources

A radioactive material, defined as "any material or combination of materials that spontaneously emits ionizing radiation", has enough energy to split atoms and molecules (13). When radioactive materials pass through body tissues they ionize the tissue molecules, and may result in two severe effects: important molecules may be destroyed,

and fragmented molecules may regroup to form harmful compounds. The physical effects of this exposure can vary from acute reactions (vomiting and fatigue) to chronic effects which can lead to death (10).

The improper disposal of radioactive wastes has been a serious threat to some Massachusetts communities. In 1978, the city of Attleboro found an illegal dump in a public park. Within the same year a landfill in Norton was found to have an abnormally high radioactivity level (1).

Situations such as these pose a threat to water supply and public health. If radioactive materials were to reach the groundwater they could be very dangerous. For this reason it is important to use protective measures. DEQE monitors radionuclides in surface and groundwater public water supplies. Approximately 15-25 samples were analyzed each quarter in 1981. An additional 10-35 samples were taken at the Connecticut and Deerfield rivers, Quabbin Reservoir and the Yankee Atomic Plant in each quarter of 1981 (41). The MDC also samples for radionuclides within their water system.

Radon

222 Rn, a naturally-occurring radioactive gas from the Uranium decay series, has been recently studied in the State of Maine. It has been found to occur mostly in granitic and highly metamorphosed bedrock areas.
Deep sources of groundwater also have statistically higher levels of radon. Other findings conclude that public water supplies were substantially lower in radon than private wells, radon gas in the air of some homes exceeded recommended levels for industrial settings and radon is correlated with some types of cancer. These trends are also expected for some areas of Massachusetts in similar geologic settings.

Minor Constituents

Some of the other common although less abundant elements present naturally in groundwater include: aluminum, arsenic, boron, bromine, fluoride, iodine, lithium, and selenium. Of these, arsenic, fluoride and selenium have maximum contaminant levels set for health purposes.

2B. Sources of Contaminants

The remaining sections of Chapter Two address sources of groundwater contaminants common to Massachusetts. How the contaminants travel from the source to the groundwater is described and some preventative and corrective measures are recommended. The types of sources addressed are as follows (see Figure 10):

2B.1 Infiltration by Polluted Waters

Saltwater Intrusion
Induced Infiltration
Interaquifer Leakage
Abandoned Wells
Underground Injection Wells
Leaking Fuel Storage Tanks and Pipes
Acid Rain/Acid Deposition

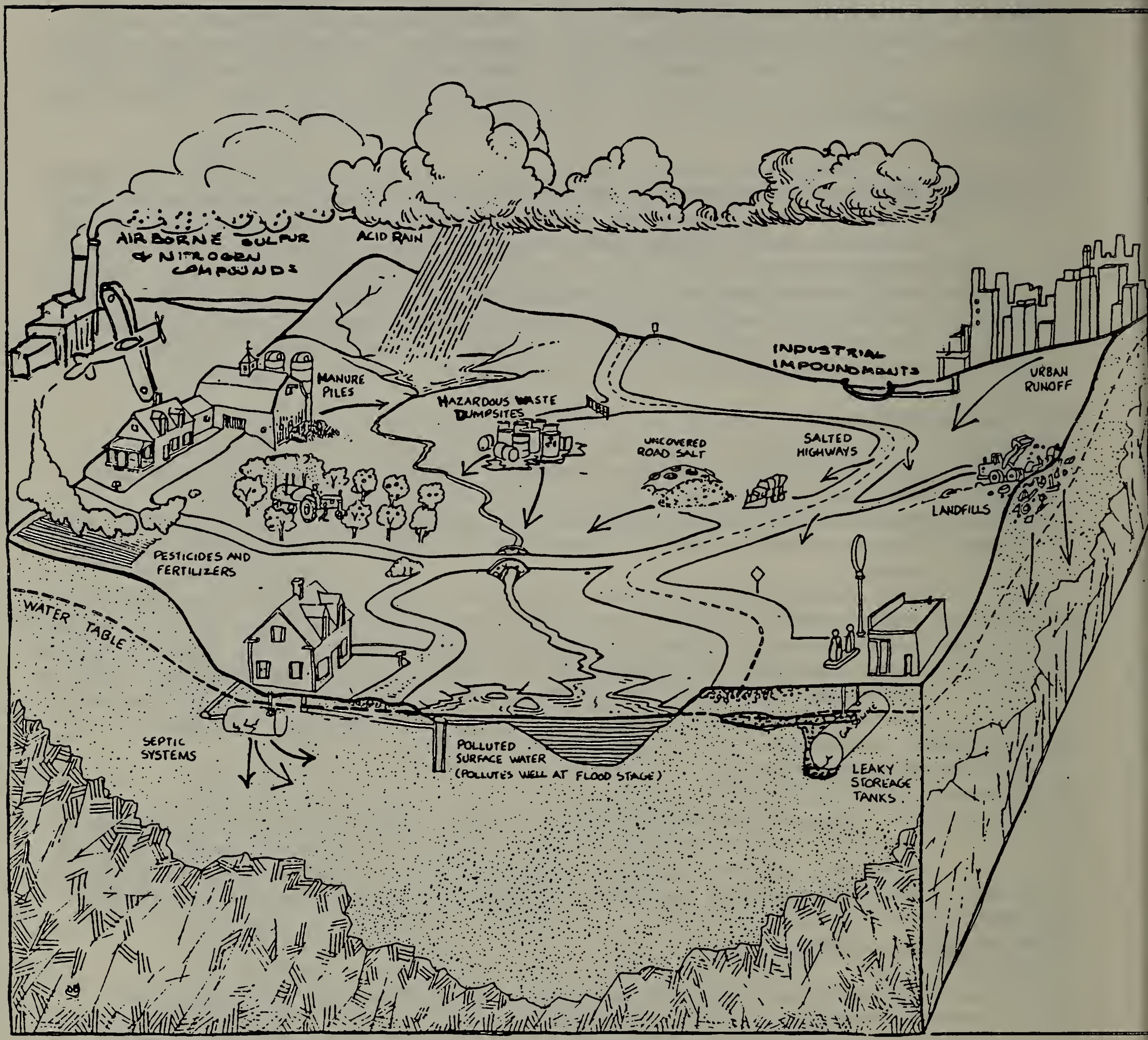


FIGURE 10: Contamination of Surface Water and Groundwater. Supplement to the New Hampshire Times, June 17, 1981, page 13.

2B.2 Disposal of Solid and Liquid Wastes

Landfills
Accidental Spills
Illegal Dump Sites
Municipal and Industrial Sludges
Land Application of Liquid Wastes
Surface Waste Impoundments
Septic Systems
Animal Feedlots

2B.3 Land Uses and Activities Which Can Pollute Groundwater

Road Salting
Pesticide Application
Mining

2B.1 Infiltration of Polluted Waters

A clean, well maintained municipal or private groundwater drinking source can become polluted from the infiltration of contaminated waters. This can be caused by excessive withdrawals which draw polluted waters into the aquifer, by saltwater intrusion, by polluted surface waters entering the well, by injection of wastes into other wells in the aquifer, by leaking pipes or storage tanks, or by acid precipitation percolating into the groundwaters. A discussion of each follows, explaining how the pollutants from that source make their way into the groundwater. Section 2A explains the health and environmental effects of the various pollutants.

Saltwater Intrusion

Excessive pumping can induce saltwater intrusion in two ways. Under normal conditions, the outward flow of groundwater prevents any inflow of saltwater. When withdrawal is high, the outward flow of groundwater is reduced and saltwater can flow into the aquifer. In other cases, the freshwater aquifer may lie on top of saltwater. The more dense saline aquifer does not normally mix with the freshwater zone lying above. If withdrawal is excessive, the cone of depression will lower until saline water enters the well, as illustrated in Figure 11 (14).

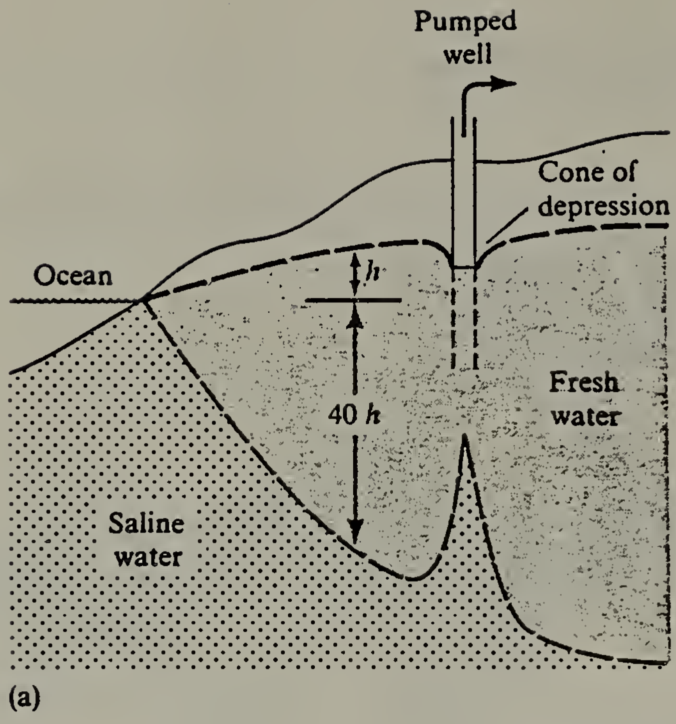


FIGURE 11. (a) Near the coast, groundwater occurs as a lens over saline water. The height of the lens above sea level is equal to one-fortieth of its depth below sea level. (b) Heavy pumping of the groundwater generates a large cone of depression in both the upper and lower boundaries of the freshwater lens and eventually allows saline water to enter the well (15).

Cape Cod is an area where saltwater intrusion is of great concern. Large aquifers act as water supplies for most of Cape Cod, making protection a high priority. A similar situation exists on each of the islands and in some southeastern Massachusetts communities. As a result, these communities are very active in the development of groundwater protection policies.

By carefully selecting the site of a well and its depth, and by limiting the amount of groundwater pumped, saltwater intrusion can be prevented. The importance of protection prior to contamination should not be taken lightly. The costs and legal problems involved with desalination or removal of other pollutants can be extensive, and the loss of a water supply can create a critical situation.

Induced Infiltration

Inland aquifers are also susceptible to contamination from excessive pumping. Once water is pumped from an aquifer, water from the surrounding area infiltrates, recharging the system. If the surface water within the drawdown area is contaminated, pollutants can be drawn into the groundwater (see Figure 12). Excessive pumping can also extend the cone of depression (the area through which the groundwater is recharged). Under these circumstances the new drawdown area may include a source of contamination not part of the original cone of depression. Constructing the well with permeable backfill too close to the surface can also lead to contamination in times of flood (see Figure 13).

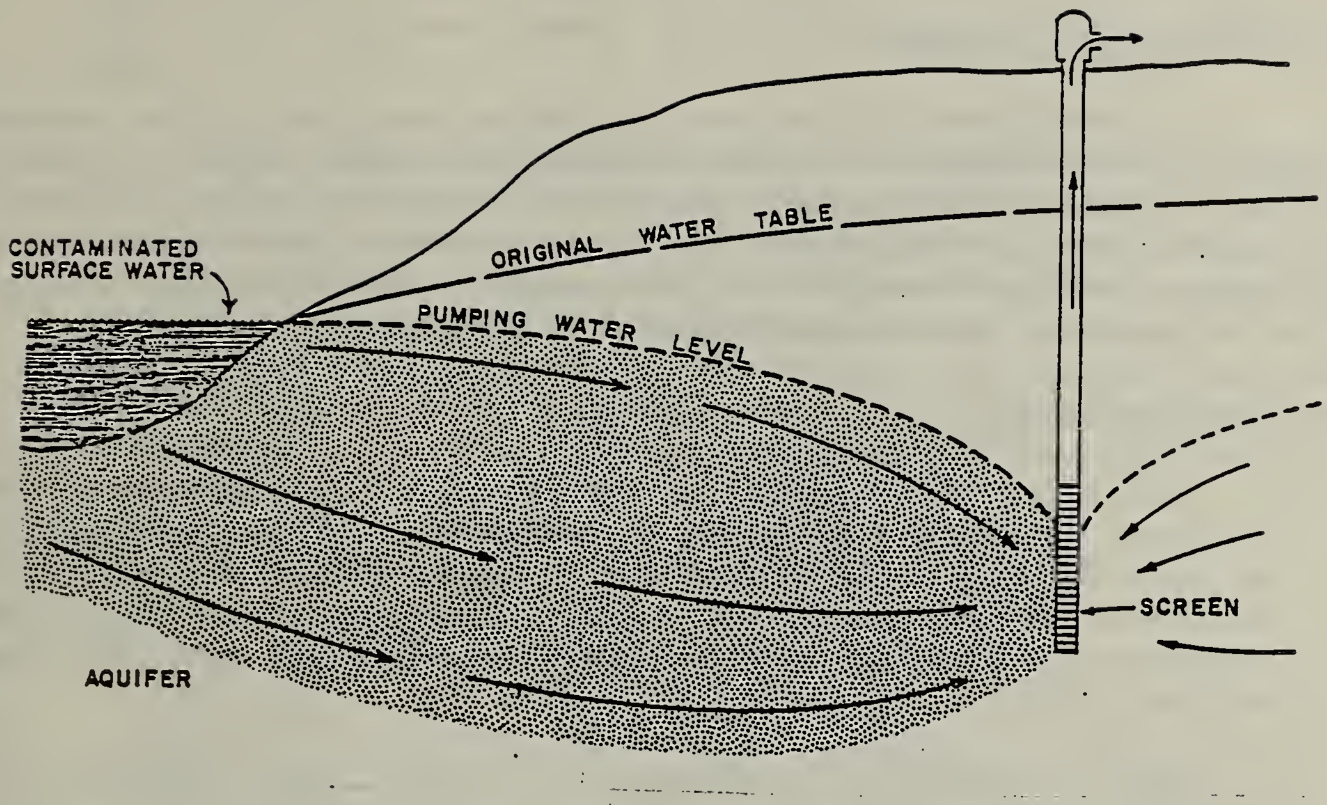


FIGURE 12. Diagram showing how contaminated water can be induced to flow from a surface stream to a well (15).

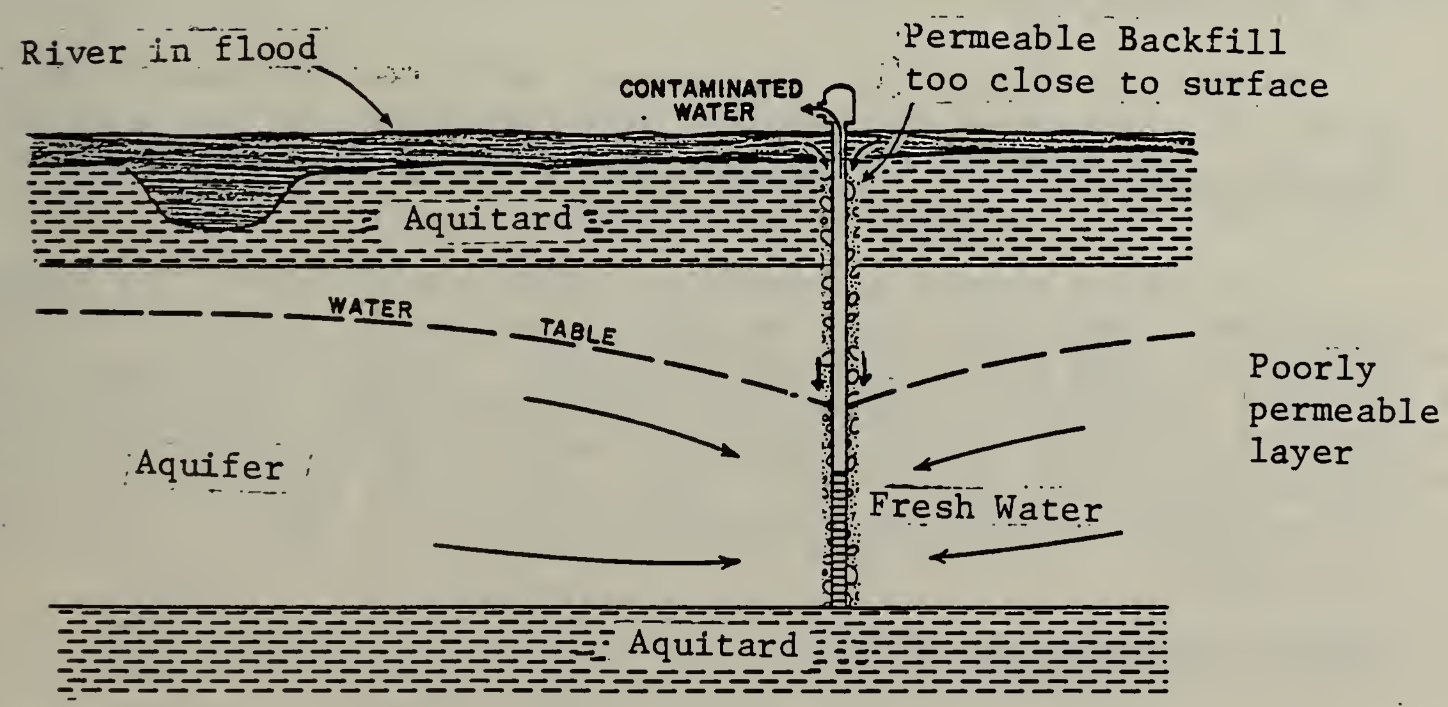


FIGURE 13. Diagram showing flood water entering a well through an imporperly sealed gravel pack (16).

Interaquifer Leakage

Interaquifer flow becomes a problem when one of two connected aquifers is contaminated. Withdrawal of groundwater from the unpolluted aquifer can induce inflow from the contaminated groundwater. The interaquifer connection may occur naturally or by man-made excavations and wells. Care must be taken to ensure that groundwater withdrawal does not encourage this problem, particularly when a disposal well is nearby.

Abandoned Wells

Wells are often abandoned when they dry up, lose their desirable qualities, or when a building is demolished. When abandoned, they should be grouted or properly backfilled to prevent the entrance of surface contaminants and to inhibit interaquifer exchange. These practices are not currently required by law in Massachusetts. Thus many abandoned wells are left open.

The problems with groundwater contamination attributed to abandoned wells are diverse. Some people dump small amounts of wastes (e.g., waste oil) into dried up wells. Abandoned wells are also often used for illegal dumping. When wells are used as disposal sites, groundwater contamination can easily occur because of the direct connection between the wells and aquifers.

Pollution of groundwaters from abandoned wells can also develop if the casing of a well is removed or if it corrodes and develops a leak. Polluted water (or saline water) can then flow from one aquifer to another.

Surface contaminants such as stormwater runoff, contaminants from accidental spills, and many other pollutants can also flow into improperly plugged wells. Also, there is the danger of children and adults falling into open wells (18).

Uncapped artesian wells can produce additional problems at the surface level. If these wells are flowing, water may flood the land surrounding the well. The constant flowing has been known to produce swamps or wash soils away (18).

In order to protect groundwaters, abandoned wells must be properly backfilled. Where more than one aquifer is present, impermeable seals should be placed between the aquifers (18). The well casing should be removed, if possible. The well and sealing equipment should be cleaned before the seal is put in place to prevent contamination from being introduced into the aquifer (18). These precautions will help to ensure that abandoned wells do not threaten the quality of aquifers now and in the future.

Underground Injection Wells

In addition to the more common methods used for removing water, oil gas, or other substances from below the earth's surface, certain types of wells are used as disposal sites for industrial wastes, sewage effluent, stormwater, and cooling water. Underground injections is the deliberate placement of a fluid into a well, either under pressure or by

gravity flow. The wells used should be constructed for this purpose only. As discussed above, abandoned wells are also used for waste disposal.

Large scale underground injection of wastes began when oil and gas industries needed a site for the disposal of saltwater and other production wastes. The use of injection wells increased sharply and was even encouraged when surface water quality controls were established (19). However, contamination of aquifers used for drinking water has occurred (see Figure 14). Issues of concern are the toxicity and persistence of the substances being disposed, the difficulty involved in monitoring groundwater, and the problems involved with decontamination of groundwaters (19).

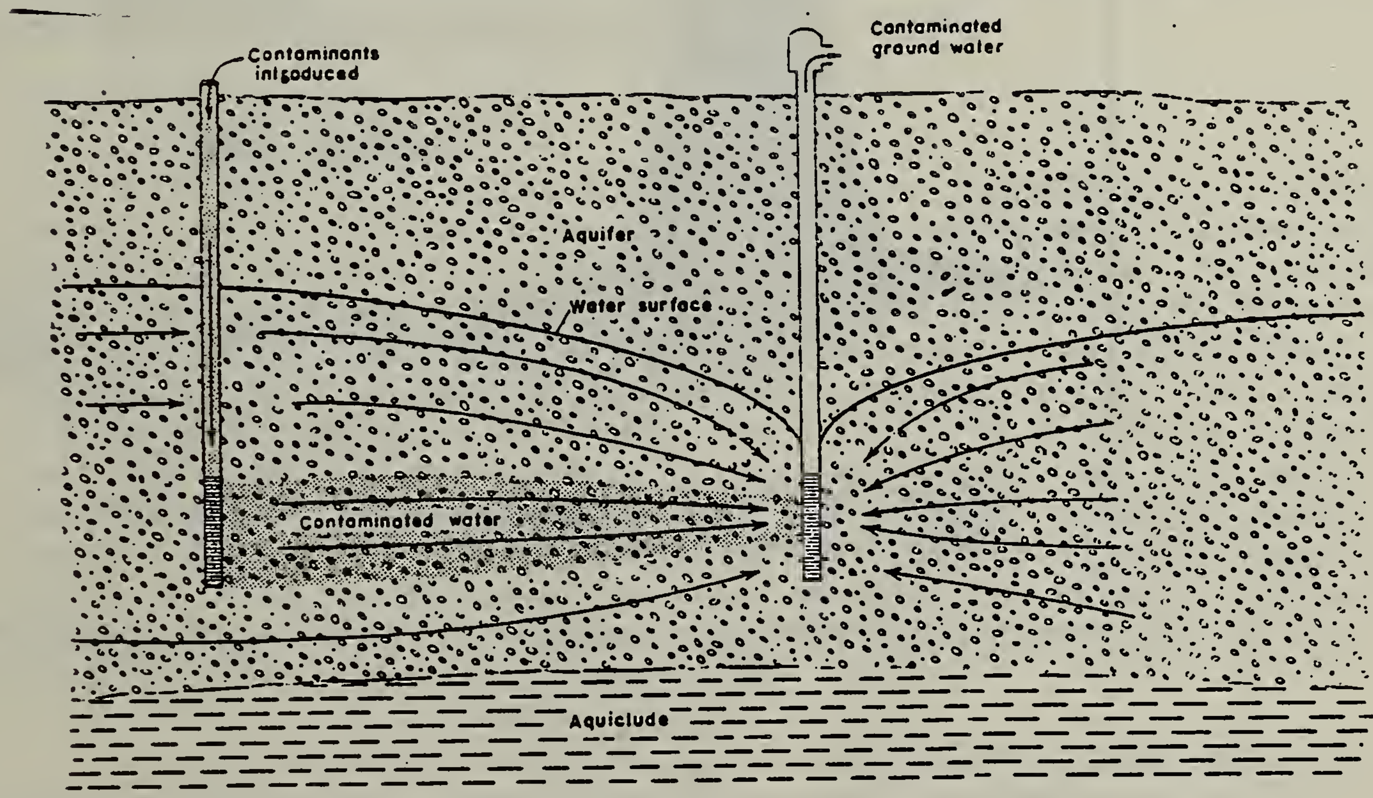
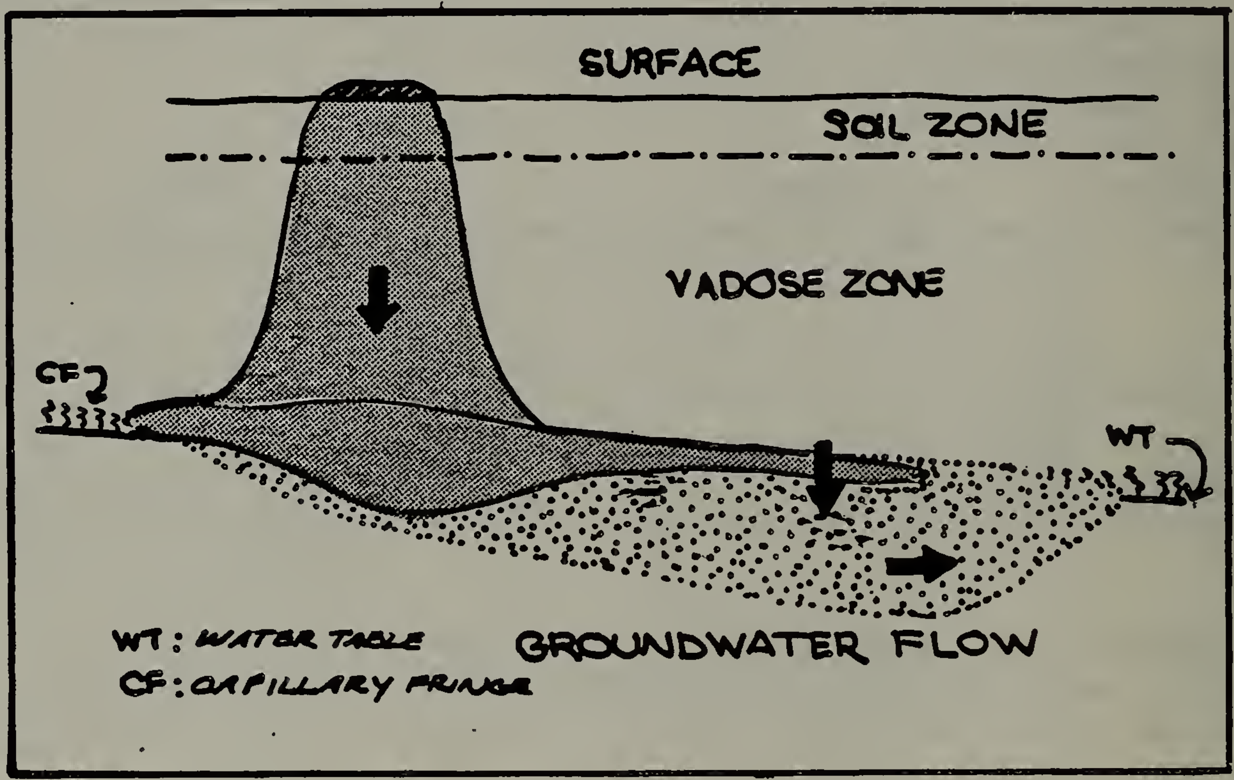


FIGURE 14. Diagram showing movement of contaminants through a well to a nearby pumping well (17).

To help protect groundwaters from this form of contamination, EPA began the Underground Water Source Protection Program which is designed to regulate underground injection practices under the authority of the Safe Drinking Water Act. Also known as the Underground Injection Control Program (UIC), this program designates five classes of injection practices which vary according to the design and purpose of the wells. Inventories of the location of such wells, well construction features, the type and quantity of wastes injected, and the contamination potential of these wells are being prepared for Massachusetts under the UIC program. The Department of Environmental Quality Engineering is also preparing regulations which address the location of wells, the types and amounts of substances injected, and the well design.

Leaking Fuel Storage Tanks and Pipes

Groundwater may become contaminated when subsurface fuel storage tanks and fuel pipes corrode to a point where they leak. The escaping fuel saturates the surrounding soil and eventually enters the aquifer. These petroleum products form a film on the top of the groundwater which floats (see Figure 15). Because some of the constituents separate and are adsorbed onto soil particles, these products are very difficult to clean up.



CROSS SECTION

FIGURE 15. Oil Moving With Shallow Groundwater Intercepted By Ditch Constructed Across Migration Path (20).

Historically, storage tanks have been made of steel and have an average life span of only 13 years (21) due to bottom corrosion, induced when atmospheric moisture condenses on the walls of the tank's air space and then settles to the bottom of the tank below the lighter petroleum products. Typically, these tanks are located at service stations, fuel companies, highway department garages, car dealerships, garages for commercial car and truck fleets, and at homes when large tanks are desired. Regular testing of the tanks is not common and often they are used until the owner detects that fuel is disappearing.

Preventative measures such as regulating the type of tanks used, the installation methods used, and testing and replacement practices could be adopted to protect groundwaters. Fiberglass, non-corrosive or corrosion inhibiting tanks decrease the risk of leaking. Often these tanks are more expensive to install properly; however, their life span is considerably increased. Tanks may be installed on blocks in a concrete vault, which may be monitored for leakage. Regular testing can

show whether or not the tank is leaking. Pressure tests and daily monitoring of the fuel level are two methods of accomplishing this.

Cape Cod is one area where Board of Health regulations have been adopted in several towns (21). The regulations which govern practices, such as those mentioned above, apply to subsurface tanks holding more than 50 gallons of fuel. Provincetown enacted these regulations rapidly in the fall of 1980 after gasoline was found in cellars and sewer lines (23). The gasoline was traced to a service station storage tank located only 600 feet from a well field. DEQE and Provincetown have already spent several hundred thousand dollars on clean up of the problem (1). Protection of groundwater systems through Board of Health regulations will help to decrease the need for these expensive decontamination programs.

Acid Rain/Acid Deposition

Acid precipitation is another potential groundwater pollution source. Precipitation becomes acidic when sulfur and nitrogen oxides discharged into the air transform into acids and become incorporated into the rain (see Figure 16). Some of this acid rain is deposited on the earth's surface where it may cause changes in soils. The effect varies with the type and characteristics of the soil. Soils containing significant carbonate, having a pH of 6.0 and a cation exchange capacity greater than 15 meq (milliequivalent)/100 gm are not sensitive to the effects of acid deposition. Strongly acidic soils (pH 3.5) are only generally sensitive to increases in acidity which can produce increased leaching of metals. However, the soils with characteristics in between these two types are likely to be acidified by longterm acid deposition (24).

In the northeast, groundwater is characteristically soft and of low ionic strength. These conditions increase its vulnerability to acidification (24). Some changes which may occur in soils over time include the destabilization of clay minerals, reduction of cation exchange capacity, loss of major cations, deepening of the lime free horizon, accelerated podzolization, elevated concentrations of toxic heavy metals, increased mobilization and leachability of toxic metals, loss of important trace elements, destabilization of organic acids, changes in the composition and numerical density of soil microflora and microfauna, and a reduction of decomposition and denitrification processes (24).

These changes in soils may affect the quality of groundwater. Acidification of groundwater has been documented in research conducted in northern Europe which showed a potential relationship between acidification and metal contamination in acid groundwaters (24). This increase in metal concentration may be caused by a variety of factors such as increased soil and bedrock weathering, leaching, and the leaching of metal contaminants which have been deposited on soils from the atmosphere (24). This contamination can degrade valuable groundwater supplies.

An assessment of groundwater resources is needed in order to better understand soil susceptibility to acid. By studying groundwater chemistry, the overlying soils, and the underlying bedrock, potential problem areas can be identified.

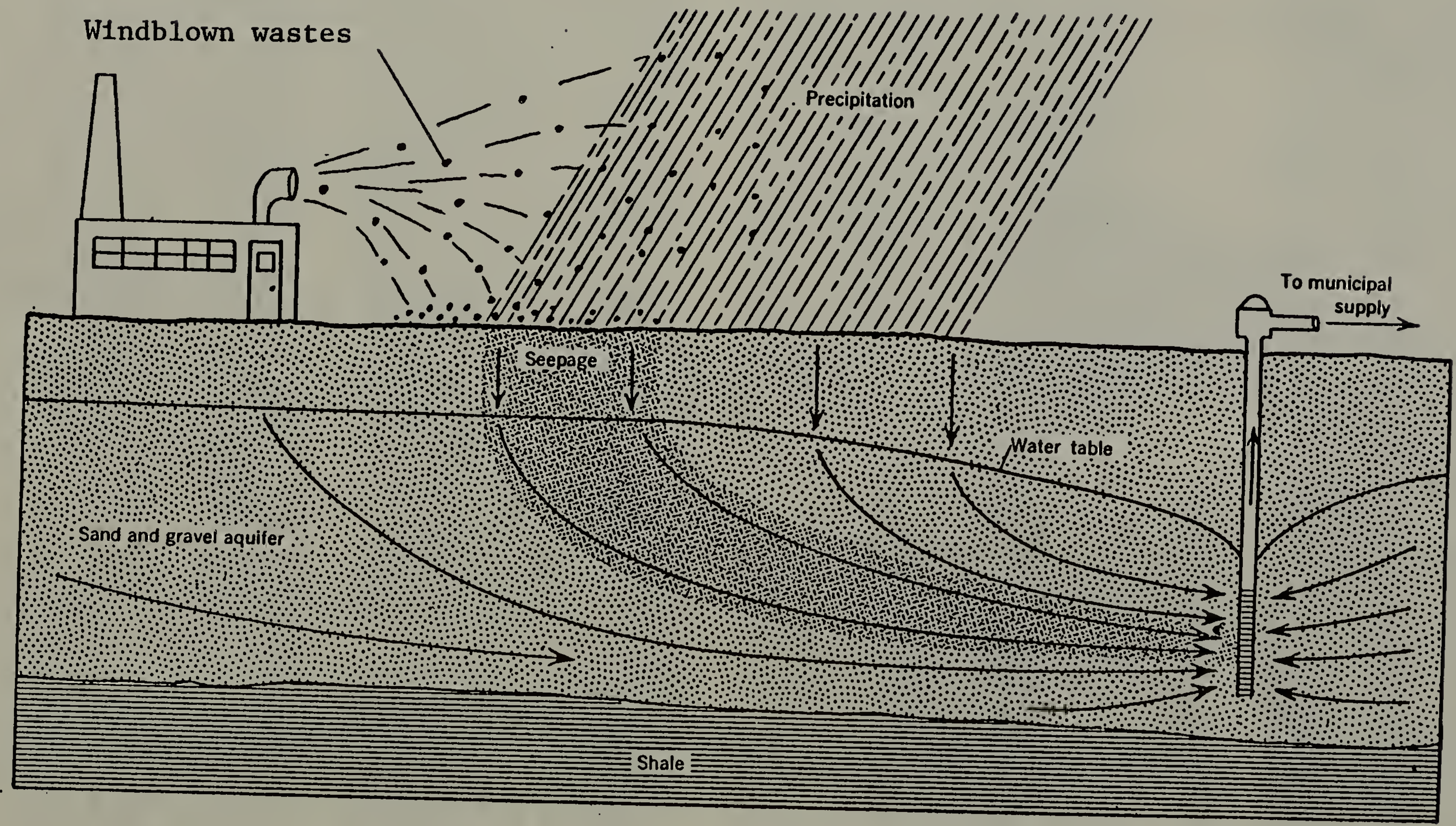


FIGURE 16. Diagram showing possible mode of entry of windblown wastes into an aquifer (17).

2B.2 Disposal/Application of Solid and Liquid Wastes

The land surface has been used for many years as the ultimate disposal site for both liquid and solid wastes. Some systems have been designed and sited to minimize their impact on surface and groundwater supplies. Others have been placed without regard to the physical environment and subsequently have released substances which pollute groundwaters.

Solid wastes of concern generally include sanitary landfills, municipal sewage and water treatment sludges, industrial sludges and animal feedlot wastes. Liquid wastes include municipal and industrial wastes placed in surface impoundments and wastes disposed of in septic tanks and cesspools.

The following sections discuss the practices as they are commonly found in Massachusetts and how they can affect groundwaters.

Landfills

The disposal of municipal and industrial waste on the land is a major source of groundwater contamination throughout Massachusetts. Large volumes of wastes, placed in many sites, the hazardous nature of some landfilled material, and inadequate design of most sites have contributed to groundwater contamination.

Throughout Massachusetts, solid wastes are placed in sanitary landfills where the refuse is compacted and then covered with earth. The cover is required to be placed on the compacted refuse at the end of each day. This daily cover reduces odors, vermin, insects, and prevents fires from starting and spreading.

The groundwater pollution problem arises when precipitation percolates through the refuse material and leaches out various contaminants that can be highly toxic. Freeze and Cherry (25) list the representative ranges for various inorganic contaminants in leachate from sanitary landfills. Very high concentrations of total dissolved solids (5,000-40,000 mg/l) and dissolved metals can be found in landfill leachate. Besides these inorganic contaminants, many organic compounds of various concentrations have been found. These are produced by the leaching of plastics and toxic constituents from liquid industrial wastes placed in the landfill.

Figure 17 shows a conceptual diagram of leachate generation and groundwater contamination. Also shown is the water table mounding process which may form as a result of water infiltrating through the refuse. If leachate springs or breakout develops, additional surface water pollution can result. The water table mounding causes greater contamination of the groundwater as a result of both the extended contact of the refuse with the groundwater and the outward movement of groundwater flow from the mounded water table.

If the landfill is located over relatively permeable materials, such as sands and gravels or over highly fractured bedrock, the leachate

may migrate in a plume and contaminate large areas of groundwater (see Figure 18).

If certain precautions and design considerations are included in the siting of a landfill, groundwater contamination can be kept to a minimum or eliminated. Liners, leachate collection systems, and measures to lower the water table are a few examples of ways to control and prevent the contamination of groundwater. One of the most important considerations is the actual site location. New landfills should not be located over aquifers that are currently drinking water sources or have the potential for supplying drinking water in the future. Modern design criteria and performance standards should be included in the siting of all future landfills.

For existing landfills which may be a source of groundwater contamination, mitigative measures must be employed to reduce the continued contamination of groundwater. Capping the landfill with a clay layer and using recovery wells to capture the contaminated water are some examples of mitigative measures. Groundwater monitoring wells should also be installed.

Accidental Spills

Accidental spills of hazardous materials and liquid wastes are a very serious threat to groundwater quality. Spills from tank car accidents, train derailments, pipeline ruptures, bulk and underground storage leaks, and improper storage and handling all may contaminate Massachusetts groundwaters. There is a need for a higher standard of care in dealing with materials which can have such a devastating effect on water supply.

The general process of water movement from recharge areas to aquifers determines the extent and degree of seriousness associated with contamination from spills. A spill can be a slow leak or instantaneous from a pipeline rupture or spillage from a holding tank. The downward movement of a spilled contaminant through the soil may stop or slow under the following conditions (28).

- the contaminant will be exhausted to immobility
- it will encounter an impermeable layer
- it will reach the water table.

Exhaustion to immobility means that the spilled substance moves both laterally and vertically through the soil until the saturated soil reaches a point called the immobile or residual saturation. This point is analogous to field capacity or specific storage as discussed in Chapter One. If this condition occurs before the contaminant reaches the water table, then the groundwater contamination can be minimized with a rapid response program. If the response and clean-up does not take place immediately, then subsequent precipitation and water table fluctuations may carry the contaminant into the groundwater reserve.

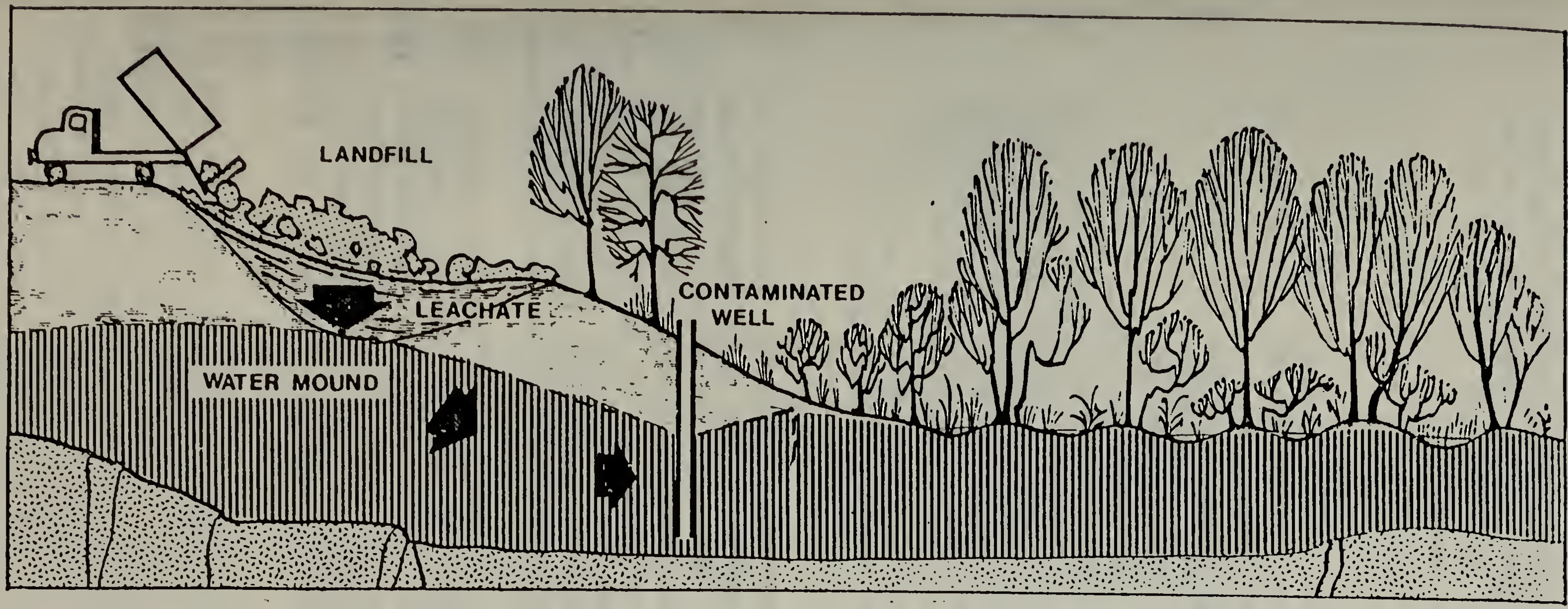


FIGURE 17. Contamination of groundwater by leachate from landfill (26).

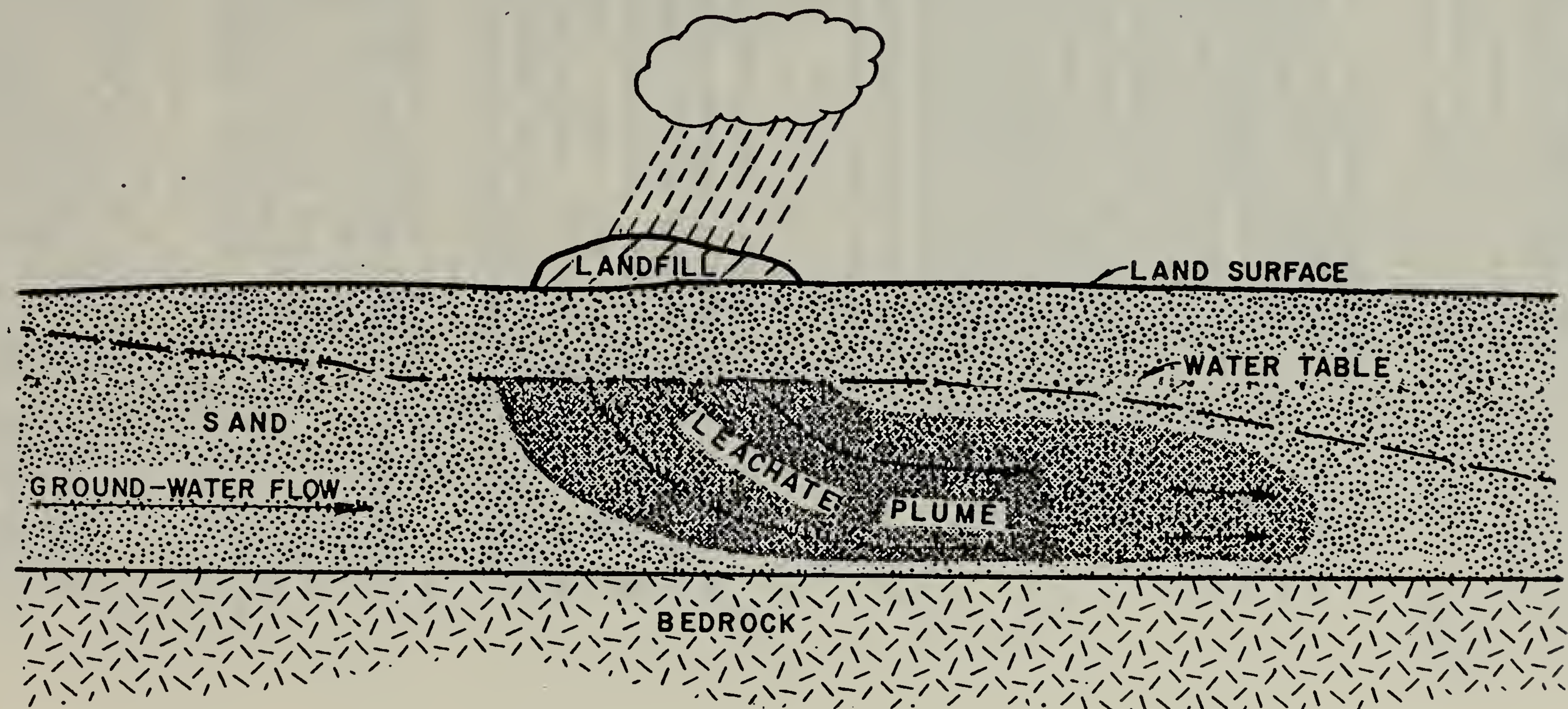


FIGURE 18. Leachate Plume in Sand and Gravel (27).

If the contaminant reaches an impermeable layer or confining bed as described in Chapter One, the plume will move laterally until it reaches immobile saturation or until it reaches a surface breakout point. If this breakout occurs, then additional surface and groundwater contamination can result (see Figure 19). This situation occurs only if the water table is below an impermeable layer or confining bed.

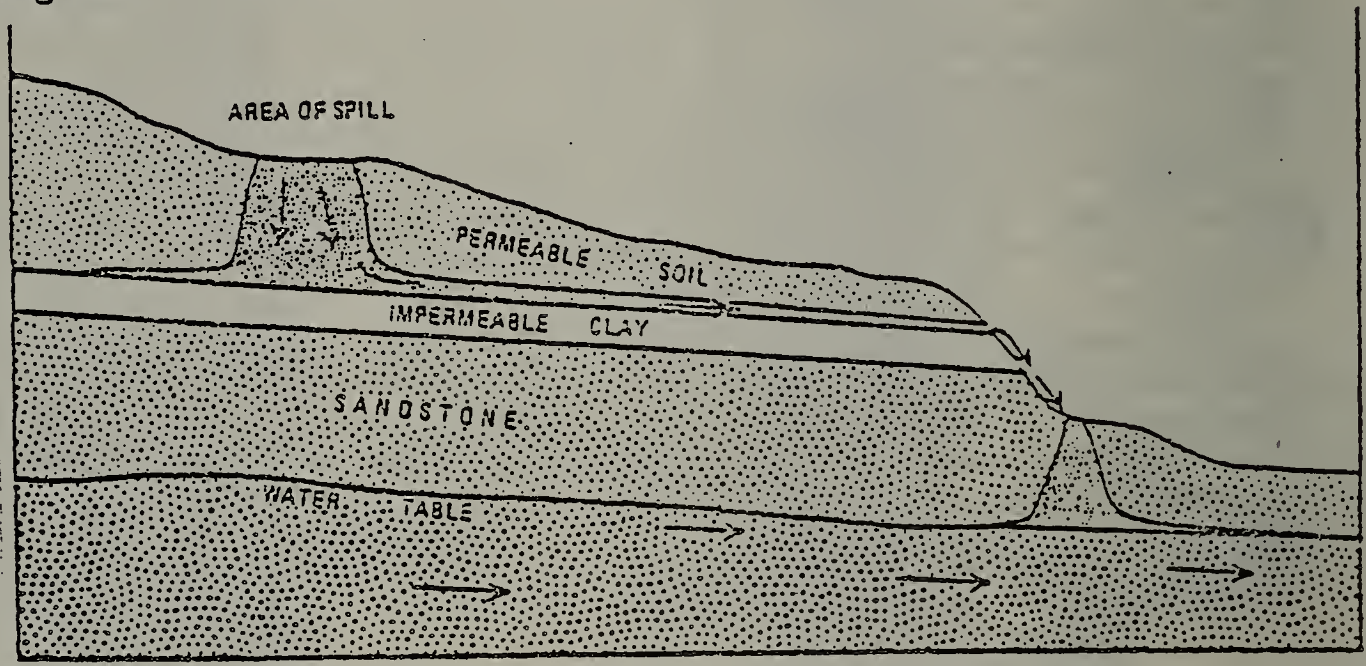


FIGURE 19. Demonstrates Possible Migration to Outcrop, Followed By Second Cycle of Groundwater Contamination (28).

In most parts of Massachusetts the water table is very close to the ground surface. However, the severity of the spill depends upon the specifics of the spill incident: the characteristics of the spilled material, the volume released, and the permeability of the soil. Spills of oily materials will form a plume elongated in the direction of ground water flow and will be suspended above or float on the water table (see Figure 15). However, even though oils are considered insoluble in water, where some mixing does occur groundwater will become contaminate

The degree of water contamination as a material enters the soil an reaches the groundwater varies greatly. It depends upon the varying degrees of attentuation of the material as it moves through the soil, t degree of aerobic and anaerobic biological degradation, chemical reactons, solubility, combined reactions with existing materials and also groundwater flow, dilution effects and mixing capabilities of the groun water system (28).

The assessment of the damage from a spill is often difficult and can involve numerous methods. Some of these include installation of groundwater monitoring wells, surface water sampling, surface geophysic techniques, aerial photography and geophysical well logging which consists of various measuring techniques (electric, gamma-ray) to determine the direction and rate of movement of the contaminant, and to estimate the contaminant attenuation capacity of the subsurface materials. Any of these assessment methods can be used to assist in the design of the remedial clean-up measures.

A few of the clean-up techniques that are successful for various types of contamination incidents are as follows:

a. Soil Removal - The removal of the contaminated soil is possible as long as the material has only moved a few feet below the soil surface, and the volume of soil to be removed and disposed of is not excessive. This method is considered a rapid response technique to capture the contaminant before it reaches the water table.

b. Trenching and Skimming - Trenches, ditches or pits can be constructed downgradient from spills that are expected to remain shallow (6-8 feet). The trenches must be dug deep enough to intercept the water table. The contaminant is then collected by pumping the water and associated contaminants from the trench. It is important to remember that this method will only be effective for spills that are not expected to percolate deeply and also for those contaminants that float on the water table or are trapped on a confining layer above the water table.

c. Recovery Wells - When the contaminant moves below the level where trenching and skimming are effective, high capacity withdrawal wells can be constructed. As explained in Chapter One, a cone of depression forms when pumping groundwater. Since the contaminant will flow with the groundwater to the well, it can be withdrawn along with the withdrawn water. Proper location and construction of the well is necessary for maximum contaminant recovery. An adequate filtering and disposal system for the collected contaminant must be provided.

d. Biodegradation of Petroleum and Chemical Spills - There are many organisms within the soil, groundwater and surface water which are capable of biologically degrading organic molecules. Bacteria and fungi are the most common organisms that can break down these materials. This technology is still in the experimental/trial stage and may be a valuable tool for clean-up.

e. In-place Detoxification - For most of the other clean-up techniques, the contaminated soil or water is removed and a disposal problem results. Either large volumes of contaminated water or high quantities of contaminated soil material must be disposed of. An alternative is to treat the contaminated water and soil on-site to eliminate this problem. Mobile treatment systems have been developed for inplace clean-up and detoxification at spill sites. The spill is first contained as well as possible and then the individual chemical treatment process begins. The U.S. Environmental Protection Agency employs this treatment system at a number of spills and hazardous waste sites throughout the country.

F. Foams and Gelling Agents Foams and gelling agents are used mainly to contain and control spills of hazardous materials. They are very good for maintaining surface control of spills over relatively nonporous surfaces. Gelling agents combine with the contaminant to form a gel which is then easy to remove. Spread of the contamination is minimized.

The Department of Environmental Quality Engineering has prepared an Environmental Emergency Response Plan (29) which outlines the procedures, authorities and responsibilities of the Department in the event of an environmental emergency. Cities and towns in Massachusetts should be aware of and familiar with their own responsibilities in the event of spills and emergencies.

Illegal Disposal Sites

Many industries have been and still are disposing of toxic and haz ardous materials by illegal and hazardous methods. In some cases, the person or persons responsible for the damage is unable to be identified and to be charged with the responsibility of cleaning up and compensating any affected individuals. An even more troublesome problem arises when the contamination is not found until some damage to individuals has occurred. The Massachusetts Hazardous Waste Management Act of 1979 calls for the Department to survey and publish a list of all sites where hazardous waste has been deposited or disposed of.

As of November 19, 1980, the first phase of the Resource Conservation and Recovery Act (RCRA) went into effect to manage the nation's solid and hazardous wastes. The section dealing with hazardous wastes calls for the regulation of hazardous wastes from generation through disposal ("cradle-tograve"). This is accomplished through the development of a manifest or tracking program.

Within the Department of Environmental Quality Engineering the Division of Hazardous Waste is developing a tracking program and regulations for the control of hazardous wastes in Massachusetts (available in draft). The Underground Injection Control Program (UIC) of the Safe Drinking Water Act can also be used to protect groundwaters from the disposal of hazardous materials. The program establishes minimum standards for injection well design and operation and provides for regulation of injection wells by permit or by rule. The program is intended to protect groundwaters that are existing or potential sources of drinking water (30).

Municipal and Industrial Sludges

Many municipalities must dispose of sewage sludges and effluents that are produced by the urban and industrial waste treatment processes. Sludge is the byproduct of treated wastewater. It is composed mostly of water with organic matter, small amounts of metals, and organic compounds. Both industrial and municipal sludges can contain many hazardous chemicals and metals which were removed from the wastewater through the wastewater treatment process. Sludge is first dewatered by filtration, centrifugation, or sand beds. Then it is stabilized through heat drying, composting, digesting, or chemical stabilizing.

Disposal of these wastes by incineration and landfilling has created serious environmental problems. These wastes in the form of sludge have also been applied to land surfaces by diffuse land spreading. Initial demonstration projects have shown that with proper management land application of sludges does not contaminate groundwaters.

Groundwater contamination problems can be caused by the chemicals not removed in treatment processes. Those which are easily leached through the soil can concentrate themselves in the groundwater. Those chemicals that are "attentuated" or held tightly in the soil can decay or remain immobile and are less of a threat to groundwater.

Because sludge contains nitrogen, phosphorus, and potassium, it can be a valuable fertilizer for crop lands. Though most sludges do not contain the quantity of nutrients needed to totally replace agricultural fertilizers, their use as a supplement and soil conditioner can reduce the amount of agricultural fertilizers needed.

Metals are often found in sludges at variable concentrations. This group includes chromium, manganese, iron, nickel, copper, zinc, lead, molybdenum, cadmium, and mercury. Other elements frequently associated with sludges in trace concentrations are boron, arsenic and selenium. The types and concentrations of metals which are found in sludges are dependent upon the source of wastewater. Almost all of the metals are related to contributions from industrial sources.

With land application, metal contamination of groundwater is dependent upon the concentration of metals in the sludge, the application rate, the physical and chemical soil properties, and the distance to the water table. Coarse textured soils, shallow groundwater tables, and high rates of precipitation are conditions that may allow contamination by metals. Fine grained soils with organic matter, deep water tables and low recharge rates are the most favorable conditions for land application sites. The Department will soon regulate the land application of sludge and septage under 310 CMR 29.00.

Land Application of Liquid Wastes

Municipal and industrial wastewaters can also be treated and disposed of by land application. This concept is used increasingly in the United States due mainly to the discharge limitations associated with disposal into surface waters.

The three principal treatment processes associated with land application of liquid wastes are: slow rate, rapid infiltration, and overland flow. The slow rate system (Figure 20) can be considered an irrigation system, with agricultural crops and vegetation acting as an integral part of the treatment process.

Rapid infiltration (Figure 21) is used over highly permeable soils. A majority of the wastewater that is applied to the land surface reaches the groundwater. The uptake of water and nutrients by vegetation is not a part of this system. This process is used mainly in areas where the recharge of groundwater is critical to continued use of the source. The major groundwater concern with rapid infiltration is the degree of the treatment of the

wastewater as it reaches the groundwater. Suspended solids, BOD* and bacteria are almost completely removed; however, chemical compounds such as nitrates, mineral salts and toxic organics may move freely to the groundwater and thus may cause contamination.

Overland flow is the treatment process whereby wastewater is applied to the tops of terraced slopes and allowed to flow across a relatively impermeable, vegetated slope (Figure 22). The objective of this system is to achieve a quality effluent and to remove large quantities of nitrogen and BOD.

All of these systems designed for the application of solid and liquid wastes have the potential to pollute groundwater, due to design failures or improper use of the system. Proper siting based upon climate, soil characteristics, soil depth, topography, hydrology and geology will ensure that the application of wastes to land will result in minimal adverse environmental impacts. An appropriate monitoring system is also necessary to determine the effectiveness of the land treatment.

Surface Waste Impoundments

A surface waste impoundment is a pond, basin, excavation, or pit intended or used to store, process and/or dispose of some form of liquid or semi-liquid material. It may be lined or not. Liquids are either decanted off through a pipe into some stream or waterway, into a septic system and leach field, or directly into the ground.

Surface waste impoundments pose a problem since they are typically unlined, unmonitored, and located over porous sand and gravel soils. Most are specifically designed to leak their contents (which may contain toxic or hazardous materials) into the ground. Frequently, the soils into which they seep are either water supply aquifers or recharge areas for aquifers.

In November of 1980, DEQE's Office of Planning and Program Management (32) released its findings of surface waste impoundments in Massachusetts. They located 1,962 waste impoundments at 316 sites. Each site was assessed by a rating system to evaluate the groundwater contamination potential in the area of the impoundments. Approximately 100 of these sites may show contamination of groundwater due to the waste impoundments, their contents and locations. DEQE is investigating all these sites on a priority basis. Of the 316 sites investigated, 93 have been determined to contain no hazardous waste and require no further investigation; 68 are water or wastewater treatment facilities; eight are confirmed hazardous waste sites currently under investigation; and one site is a confirmed hazardous waste site, which has been secured.

The degree of groundwater contamination from surface waste impoundments depends upon the following factors: soil permeability, sorption capacity, and ion exchange capacity; depth to the water table; rates of precipitation and evaporation; and the nature and volume of the wastes. Nearby groundwater withdrawals can also affect the rate and extent of concontamination. Thus the groundwater flow system must be determined to estimate the overall impact of the waste impoundment on groundwater quality.

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* Biochemical Oxygen Demand - Measure of oxygen demanding organisms. The higher the number, the more polluted the substance.

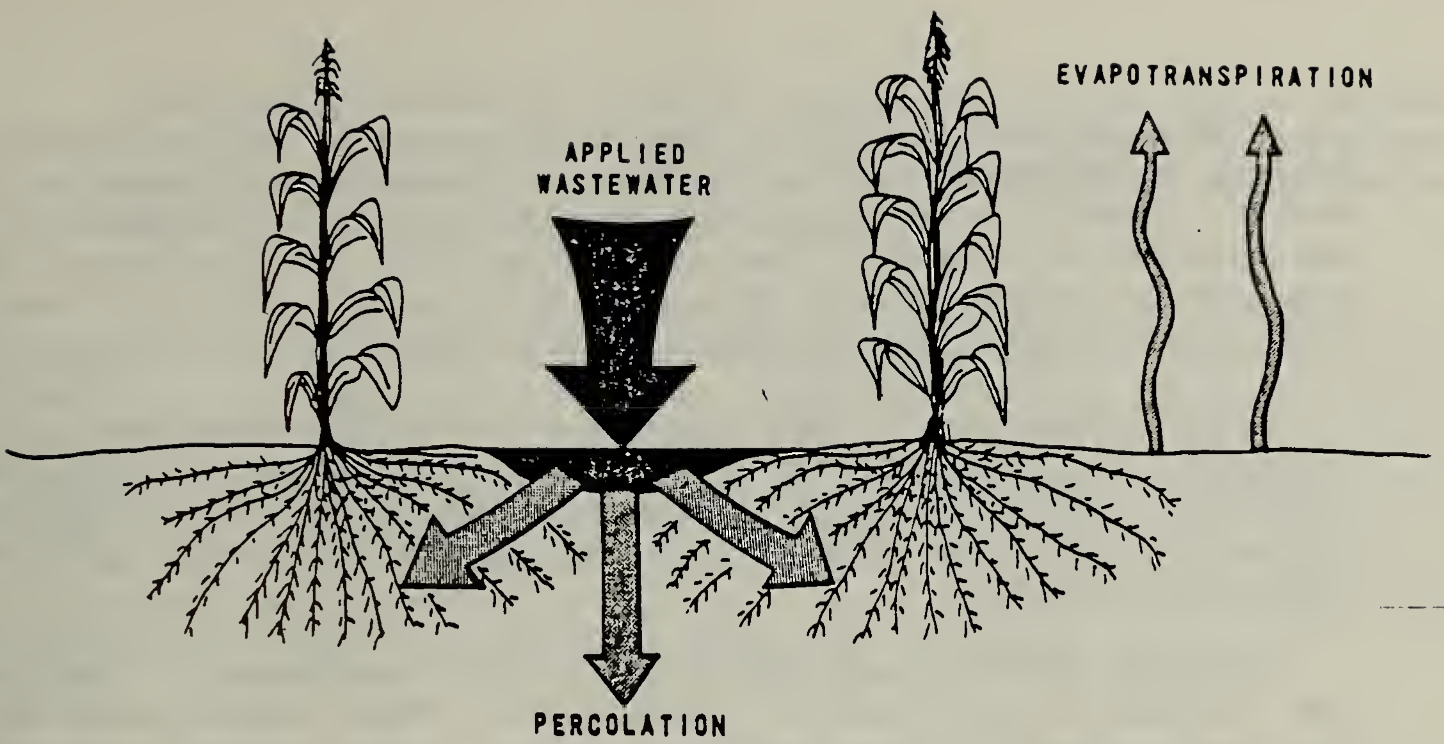

Figure 20: Slow Rate Land Treatment. (31)

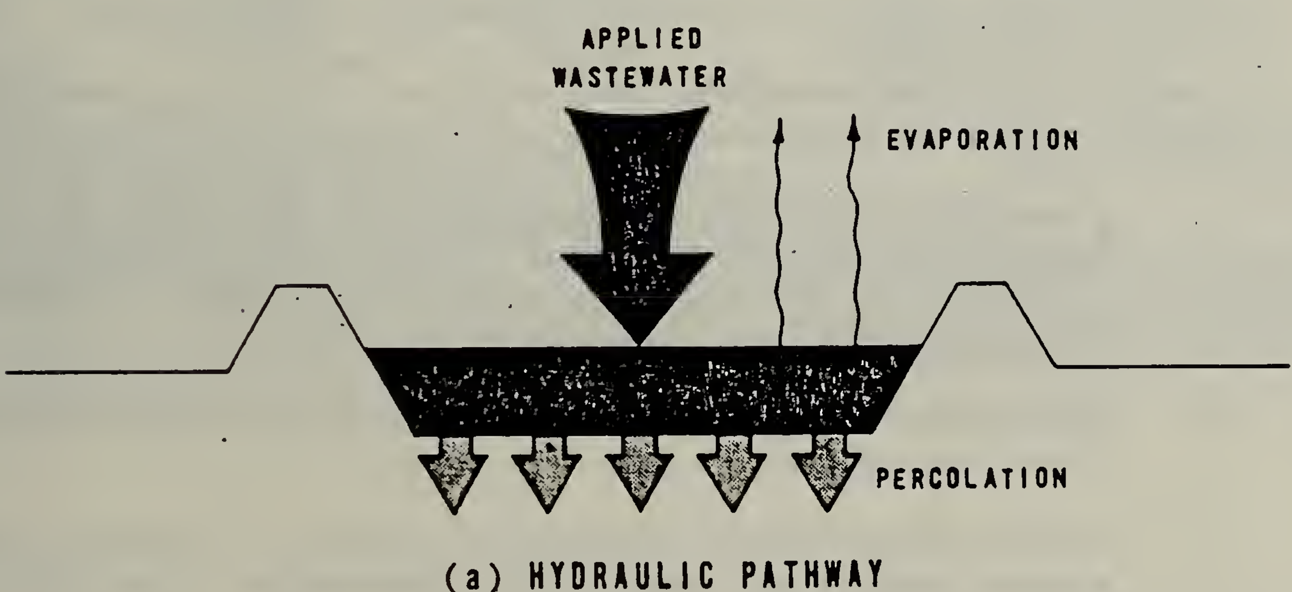

Figure 21: Rapid Infiltration. (31)

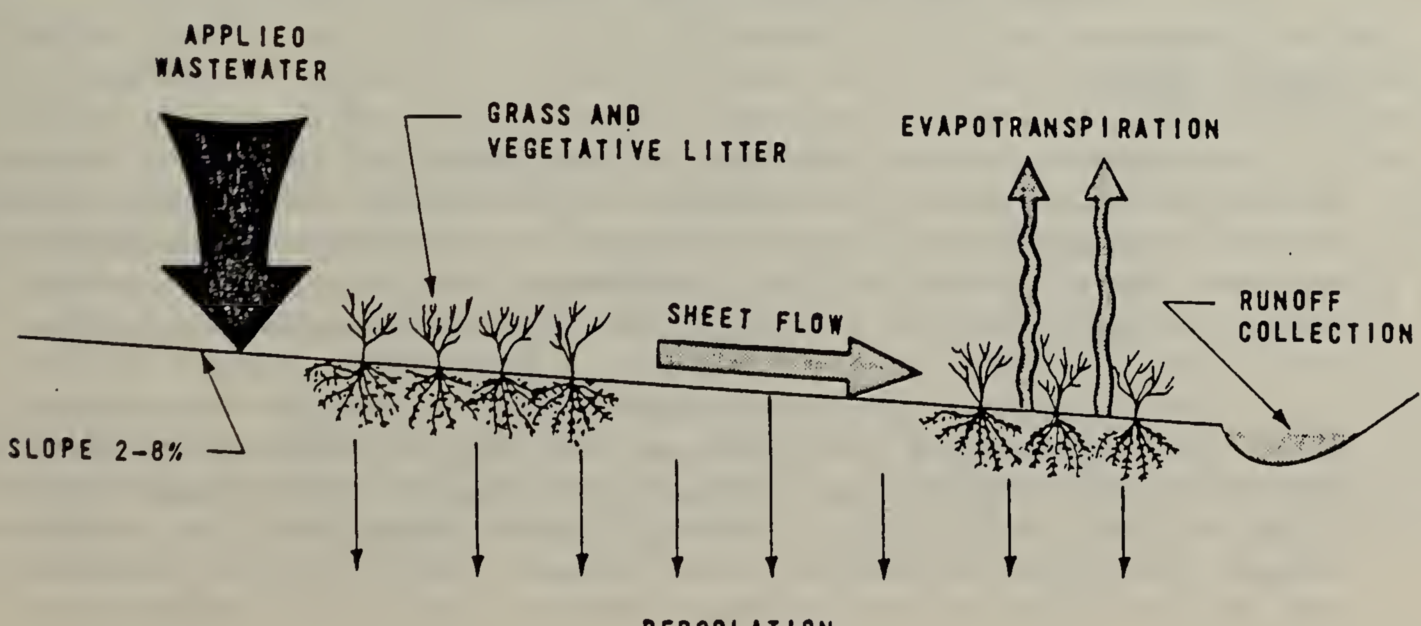

Figure 22: Overland Flow. (31)

There are many activities and practices in Massachusetts that use surface impoundments for the storage, processing and disposal of liquid wastes. Domestic wastes are often stored, treated and disposed of through impoundments or lagoons. Most are designed for infiltration of the wastewater into the ground. Some are lined and the liquid effluent is treated and discharged to surface waters, and others use percolation beds.

Many industries in Massachusetts use surface impoundments as a part of the overall treatment of their wastes. Stabilization ponds, usually in series, are employed for additional treatment of the industries' wastes. The nature of the waste determines whether the groundwater will become contaminated or not.

Besides domestic and industrial surface impoundments, Massachusetts has a number of agricultural impoundments. These impoundments are used for the storage, treatment and disposal of animal wastes. Animal waste products may contribute total dissolved solids, BOD, COD, nitrogen compounds, phosphates, chlorides, coliform bacteria, and other constituents that can be very harmful to the groundwater quality. Since most agricultural impoundments are unlined, they have the same potential for contaminating groundwater without proper treatment of the wastes.

Bowley (32) recommends the following as a result of a survey of waste impoundment sites in Massachusetts:

- Massachusetts should develop a set of comprehensive waste impoundment regulations that include criteria for technical design, siting, hydrogeological review, operation and groundwater monitoring.

- Massachusetts should develop enforcement structures for these regulations.

- Massachusetts should develop an automated data management system capable of transferring information from federal data management systems.

- Funding for the clean-up of abandoned surface impoundments must be sought from the federal government to protect the future quality of the groundwater.

Septic Systems

A common cause of groundwater pollution in the United States is effluent from improperly functioning septic tanks and cesspools. Individually of little significance, these devices are important when they are looked at as a whole because of their abundance and occurrence in every area not served by municipal or privately owned sewage treatment systems.

A septic system is composed of a septic tank and a leaching field or pit. The septic tank functions as a holding chamber where the solids settle out and biological decomposition occurs. The liquid from the tank flows to the leaching field where it percolates into the ground and additional biological breakdown takes place. Soils contain bacteria, fungi and insects that use the organic material that is in wastewater.

If there is adequate distance between the bottom of the leaching field and the groundwater table, and the intervening soil organisms have the capacity to remove organic matter, most wastewater contaminants will be removed before reaching the groundwater.

Leaching fields that discharge directly into the groundwater or close to the water table may contaminate groundwater supplies. In properly functioning septic systems, some nitrates (NO) are discharged to the groundwater. However, many septic systems, closely spaced, may contribute nitrates in excess of safe drinking water standards (see Figure 23). Additional problems can occur when septic systems are placed in sand or gravel deposits with shallow water tables. Since the wastewater percolates more rapidly, little decomposition takes place and the effluent reaches the groundwater virtually untreated.

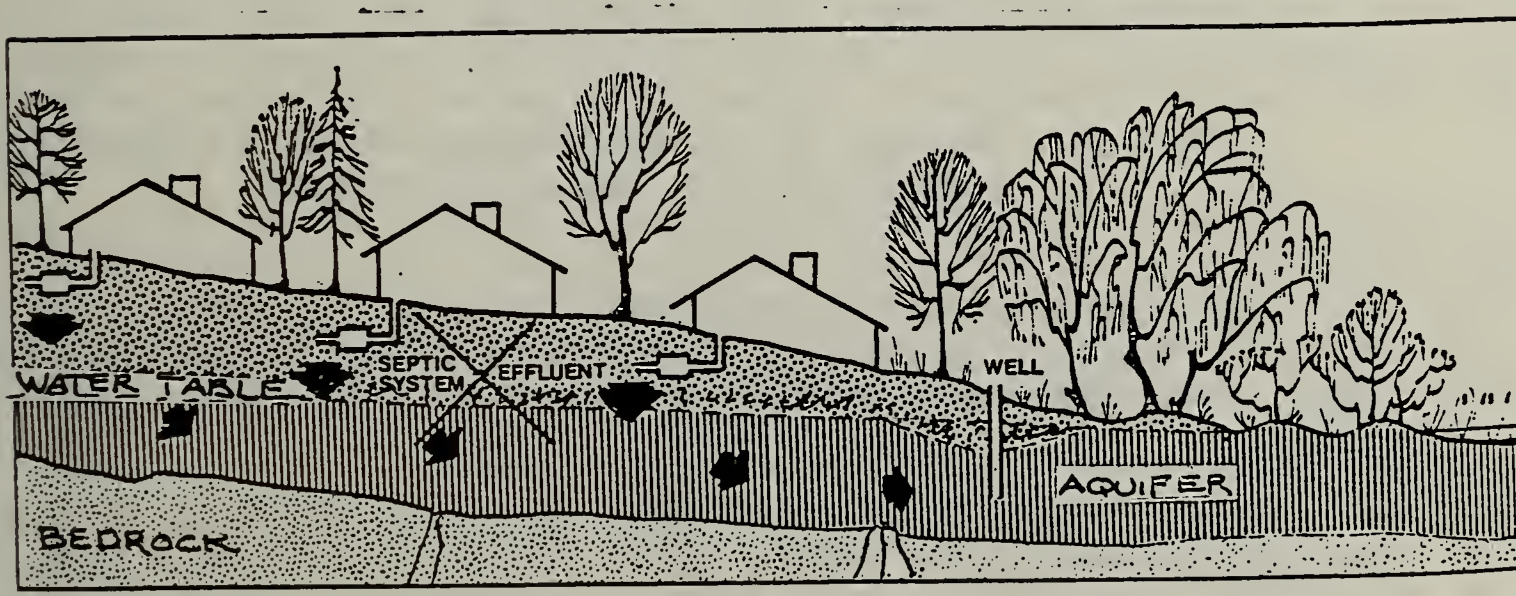

FIGURE 23. Contamination of groundwater from malfunctioning or poorly sited septic systems (26).

Since septic system operation and maintenance is largely the homeowner's responsibility, it is important that the homeowner be made aware of harmful chemicals in some products which pass through the leaching field to the groundwater. Septic systems operate on the principle that bacteria and soil anthropods in the septic tank and leaching field break down the wastes into harmless products. If chemicals which kill these organisms are poured down the drain, the wastes will not be completely treated. Therefore, all pesticides, cleaning chemicals (including many septic tank cleaners), solvents, paints, and other toxic chemicals should not be placed in the septic system. Without the biological processes to break them down, the solids begin to build up, soil pore spaces and pipe openings become clogged, and breakouts of wastewater over the leaching field can occur. Untreated wastewater can then be directly discharged to surface and groundwater and can enter nearby wells (see Figure 24).

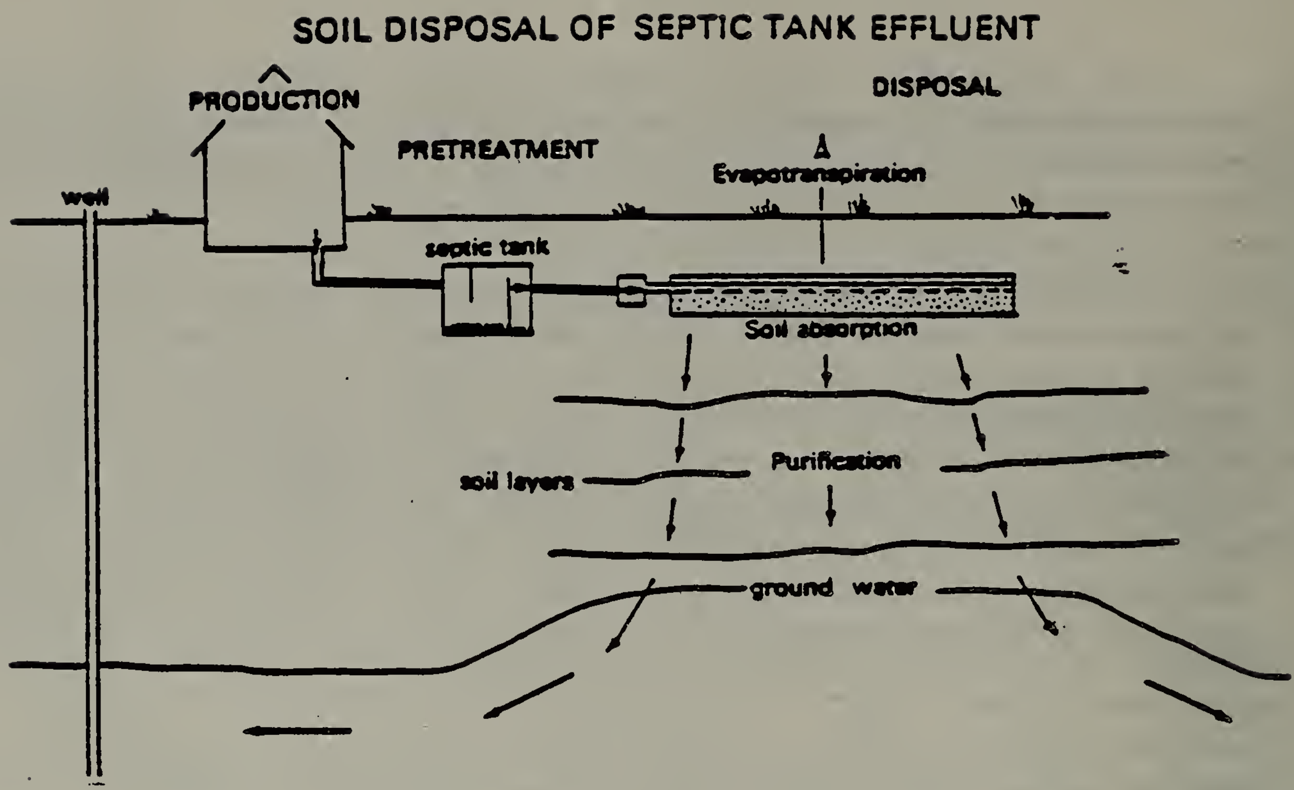

FIGURE 24. Disposal of Household Wastes Through a Conventional Septic Tank-Soil Absorption System.

Local authorities have reduced groundwater pollution from septic tanks by controlling lot size in aquifer recharge protection zones (21). This reduces the total amounts of contaminants that can reach the groundwater.

Regular pumping of septic tanks should be encouraged to reduce the sludge build-up in the septic tank. Otherwise the volume necessary to provide treatment is reduced below the capability of the system to treat fluids and untreated wastes go out into the leaching field where soil pore spaces and pipes eventually become clogged. A pumping frequency of once every three years should maintain proper septic system operation (21).

Animal Feedlots

Feedlots are areas where animals are confined in concentrated spaces. Although most pollution problems are attributed to cattle because they generate a higher volume of waste, sheep, poultry, and hog feedlots are also potential threats to ground and surface water quality (31). The pollution from feedlots includes manure, chemicals, and debris which contribute nutrients (nitrogen and phosphorus), bacteria, and metals.

The inputs to surface waters enter primarily in runoff; however, animals may have direct contact with surface waters within their feedlots. Pollutants may contaminate groundwaters in three primary ways: 1) runoff and infiltration directly from the feedlots, 2) runoff and infiltration from waste products collected from feedlots and applied to the land, and 3) infiltration through the bottom of waste lagoons developed to process the waste generated in feedlot operation (31).

The effects of feedlot wastes on groundwater vary greatly. The common problems are associated with phosphate, chloride, nitrate, and in some circumstances, metals. The increase in the number and size of concentrated feedlot operations has encouraged the development of Best Management Practices and treatment technologies for waste control. Often, control strategies include more than one practice. The most popular method of pollution abatement appears to be a runoff diversion - waste treatment combination (16, 34, 35, 36). When runoff is diverted from the feedlot area, the soil not only remains drier, but less feedlot waste is washed off the ground. The wastes which do wash off should be collected and treated.

Some methods of runoff diversion include the installation of upslope berms and diversion ditches, and the collection of rainfall on roofs. The runoff from the feedlot itself should be minimized by grading, shaping, and installing gravel; and the runoff should be collected in ditches or with a tile drainage network. Some common treatment methods are holding ponds and land application of the wastes (34, 16). If the feedlot is paved, periodic scraping should assist in decreasing the pollutant load from manure in the runoff (35).

For smaller feedlot operations, which are more commonly found in Massachusetts, less expensive control practices can be implemented. The objectives tend to center around reduction of the runoff velocity and volume, increasing surface detention capacity, and adsorbing the nutrients. One method is to install a buffer zone downgradient of the feedlot. This zone would have a thick vegetative cover capable of creating the desired results. A study of the effectiveness of buffer zones has shown that 82 percent of the nutrient concentration can be removed from runoff when a 12 meter buffer strip is located below a manured area (36). Other means of achieving similar results are by installing serpentine or low slope-low gradient ditches around the feedlot (34).

Management practices such as these should substantially decrease the passage of feedlot pollutants into ground and surface waters. Even with these practices, the depth of the water table and the gradient of groundwater flow should be carefully considered in selecting a water supply well site near a feedlot.

2B.3 Land Uses and Activities Which Can Pollute Groundwaters

Some of the other land activities which can contaminate the groundwater include road salting, pesticide application, and mining. A discussion of each follows.

Road Salts

Road salt storage and application practices contribute to the excessive sodium concentrations found in approximately 47 Massachusetts communities. Another 43 communities have been monitoring the sodium levels in their public water supplies due to elevated concentrations (over 15 mg/l). Municipal wells in Auburn and in Weston, near the Massachusetts

Turnpike, were closed after the salt concentration in the water exceeded 400 ug/l. In addition, a number of private wells have been severely contaminated by salt (2) (see Figure 25).

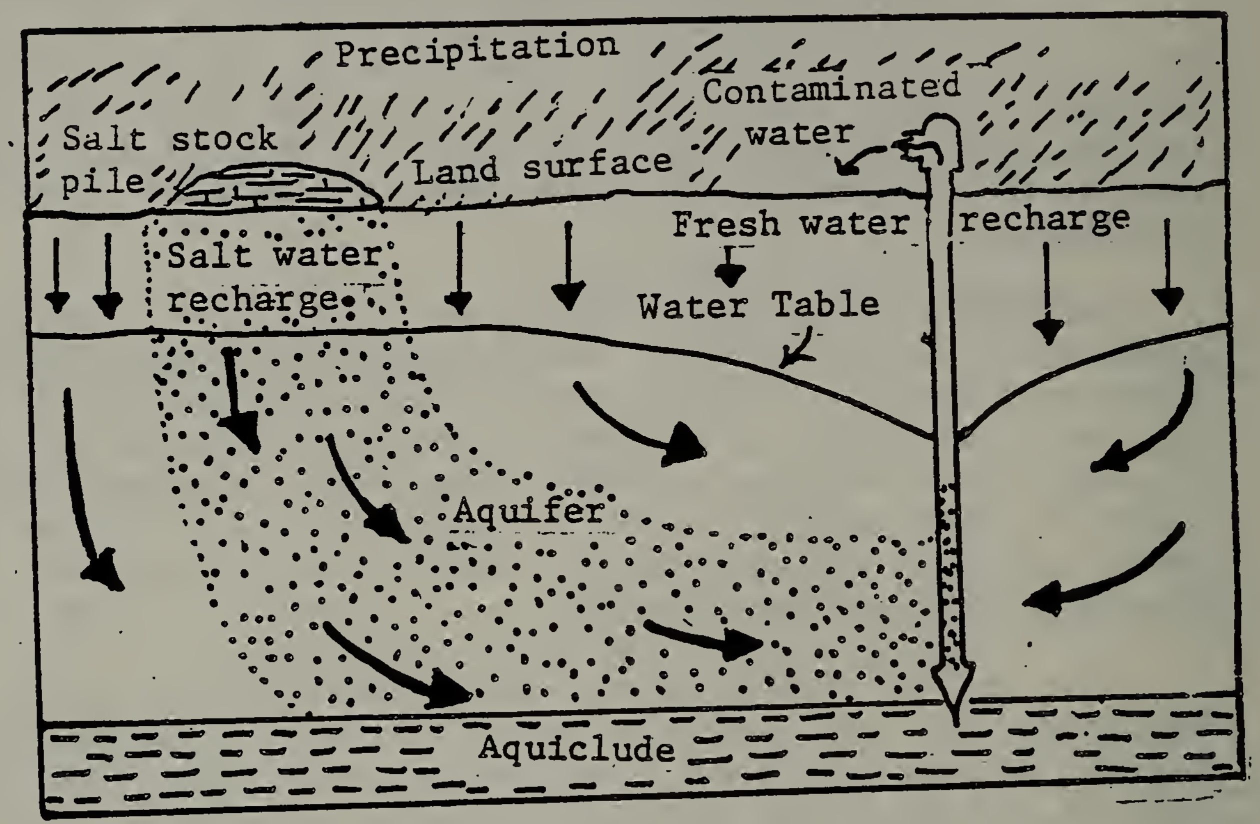

FIGURE 25. Diagram showing contamination of an aquifer by leaching of surface solids (17).

Road salts awaiting use are commonly stockpiled by communities. These piles should be placed on impermeable bases and covered with plastic sheets or stored in sheds. If these practices are not followed, there is a greater risk that water supplies will be contaminated as sodium ions are leached from the exposed stockpiles. Also, weathering may result in salt erosion and caking.

The application of deicing chemicals to road surfaces is often desirable in northern climates to ensure safer driving conditions. However, discretion should be used during application since salt-laden runoff may enter the soils adjacent to highways and leach into the groundwater systems.

To lessen the threat of groundwater contamination, communities can alter their methods of snow and ice control. Plowing roads more frequently and increasing the quantity of sand in salt-sand mixtures are two effective practices (2).

It is important to emphasize that a community should adequately inform its residents of any changes in its deicing policies. Use of local media is helpful. Drivers should be made aware of any increased need for caution and the location of areas which are no longer salted. Posting warnings in these areas is also a wise precaution.

Local officials can expect to have some negative reactions from the public if the use of salt is decreased. Under these circumstances it is necessary to stress the long-term benefits of water supply protection. Surely more cautious driving during hazardous weather is a better alternative than risking water supply contamination.

Pesticides

Pesticides enter the environment not only from their use in agricultural and silvicultural (forestry) practices, but also through the cleaning of application equipment, the disposal of pesticide containers, and the wastes from pesticide manufacturing plants (10). Problems may develop when pesticides from any of these sources enter aquifers.

Groundwater can become contaminated directly from pesticide percolation through soils, or indirectly when surface waters containing pesticide laden sediments enter aquifers. Due to erosion, more than half the pesticides used on corn, cotton, and soybean row-crops are removed with sediment transport. Research has shown that erosion control practices can result in a significant decrease in pesticide loss (37).

Pesticides should be applied in a manner which allows for effective coverage of the target area. Use should be at a time when optimal plant cover exists, the target organism is in its most vulnerable life stage, and/or the likelihood of the occurrence of a runoff event is low (38).

The Massachusetts Pesticide Board and the Department of Food and Agriculture have been delegated the authority to regulate the distribution, registration, and use of pesticides in the Commonwealth. The regulations promulgated by the Department of Food and Agriculture specify that applicators be knowledgeable in the proper procedures and techniques for pesticide storage and application.

Mining

In Massachusetts, mining activities are primarily excavation of sand and gravel (39). This form of excavation, known as surface mining, can be a threat to the quality of groundwater. The primary threat occurs when mining activities occur in aquifer recharge areas. Exposure of the saturated zone of an aquifer can leave the area more vulnerable to contaminants due to decreases in filtering capabilities. Evaporation is also increased (40).

Abandoned excavation pits have been used for unregulated dumping of refuse, liquid wastes, and salt-laden snow. If the saturation zone is exposed, leachate from these wastes can percolate into the groundwater easily. Reduced filtration capabilities (the ability of the soil to filter out materials) augment the problem (40).

Mine drainage and access systems may also threaten water quality. Acidic water containing high levels of total dissolved solids can leach from tailing piles and slurry lagoons constructed to manage mining wastes (U.S. EPA, 1977) (40).

In order to protect ground and surface waters, the following Best Management Practices for surface mining have been developed (40):

1. Mining activities should be located away from recharge areas of aquifers currently in use as, or protected for future use as, public water supplies.

2. Ensure that access roads are properly constructed, maintained and closed so as to prevent or control erosion.

3. Prohibit excavation within 50 feet of a watercourse and within 15 feet of the water table.

4. Limit active gravel removal to a total of five acres at any one time to minimize the amount of surface area susceptible to erosion.

5. Provide appropriate drainage systems to prevent ground and surface water contamination. Drainage should not lead directly into streams or ponds.

6. All topsoil and subsoil should be stripped from the operation area and reserved for restoration of the area.

7. Quickly stabilize disturbed areas by restoring overburden, replacing topsoil, avoiding steep slopes, reproducing natural drainage patterns, and replacing vegetation (40).

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CHAPTER THREE: MANAGING GROUNDWATER AT THE LOCAL LEVEL

Both because sources of groundwater contaminants are so diverse and because contaminants generally move slowly through the groundwaters, most Massachusetts communities have chosen to develop preventative protective measures for their groundwaters and aquifer recharge areas. Furthermore, communities that have had to try to clean up contaminated wells have found the operation to be difficult and very expensive, although a variety of technologies are available. Thus, for the purposes of this handbook, DEQE has chosen to focus on preventative measures available through existing local authorities. Currently, Massachusetts' local governments protect their groundwaters through:

- 3.1 Zoning
- 3.2 General Bylaws or Ordinances
- 3.3 Subdivision Regulations
- 3.4 Board of Health Regulations
- 3.5 Wetlands Bylaws
- 3.6 Local Input into State and Federal Programs

The table below compares the procedural requirements and is followed by a discussion of each.

	Statutory Authority	Who Adopts	Required Vote
Zoning	M.G.L. Ch. 40A	City Council Town Council & Town Meeting	2/3rds vote of all members city/town council and 2/3rds vote of town meeting.
Local Bylaw	M.G.L. Ch. 40	City/Town Council Town Meeting	Majority vote of all members city/town council and majority vote of town meeting unless otherwise provided by ordinance, bylaw or chapter.
Subdivision Rules and Regulations	M.G.L. Ch. 41 81m	Planning Board	Majority vote of entire membership.
Board of Health	M.G.L. Ch. 111 (M.G.L. Ch. 40)	Board of Health Meeting	For Ch. 111, a majority vote of the Board of Health. For Ch. 40 see above.
Wetlands Bylaws	M.G.L. Ch. 40 (M.G.L. Ch. 131 40) (M.G.L. Ch. 40A)	City/Town Council Town Meeting	Majority vote of all members city/town council and majority vote of town meeting unless otherwise provided by ordinance, bylaw or chapter.

3.1 Zoning

Deriving from the police power vested by the state's constitution, zoning has long been used as a means for communities to manage growth. M.G.L. ch. 40A and its amendment of 1975 (chap. 808), which is referred to as the Zoning Act, has specifically included conservation of natural resources among the purposes of zoning. Towns may enact zoning restrictions protecting local groundwaters for the following purposes: to conserve health; to prevent overcrowding of land; to facilitate the adequate provision of water, water supplies, drainage and sewerage; to conserve the value of the land including the conservation of natural resources and the prevention of blight and pollution of the environment. These are a few of the many stated purposes of the 1975 amendment.

Since zoning is a means of regulating land use, any regulation placed upon land may be looked upon by the landowner as a "taking" of one of his property rights. In such challenges, the courts look at the positive value to the community at large versus the loss of the particular use of the land to the individual. When an ordinance goes beyond the scope of just limiting uses and into the deprivation of property without just compensation, the court would rule in favor of a landowner. However, a bylaw which has gone through the democratic town meeting voting process will generally be upheld unless the party bringing suit can establish the burden of proof necessary against the bylaw.

Zoning to protect ground and surface waters has been more common in the dry, arid western states until recently when years of lower rainfall coupled with groundwater contamination has limited community water supply and towns have begun passing bylaws.

In Massachusetts the most prevalent zoning approach prevents contaminants from getting into water supplies by regulating activities and land uses which might generate contaminants in the area that feeds or recharges the underground water supply. The other approach permits all uses as long as they meet specified performance standards, e.g., discharges do not exceed specified water quality standards.

The system is similar to a stream feeding into a lake. There is no way to keep the lake free from contaminants if someone continues to discharge contaminants into the stream. Thus, the "aquifer recharge" area is one of the most critical areas to protect as it is the source of an aquifer's water

For a summary of Massachusetts communities with groundwater protection regulations, refer to Appendix B on page 81.

Evaluation of Existing Massachusetts Zoning Bylaws

Groundwater or aquifer protection zones/districts have been added to the zoning bylaws of at least 18 Massachusetts cities and towns (1) and are currently being drafted in several more. The names of the zoning bylaws are generally some type of "protection district", either Aquifer Recharge, Groundwater, Water Supply, Water Resource, Watershed, etc.. Occasionally, groundwater concerns are incorporated into wetland overlay districts. Commonly, these zoning bylaws are prepared as "overlay districts", areas superimposed on the existing zoning map with a provision that the rules of the underlying district continue except where the overlying district is more stringent.

Most of the zoning bylaws regulate uses and activities, and several also rely heavily on performance standards. A few towns only list prohibited uses (Amherst and Bourne), with the remaining uses subject to the zoning in the underlying district. Others only list permitted uses (Wilbraham and Fitchburg) with specific requirements attached to those uses. Most of the others also include a special permit, either for listed uses or in order to receive an exemption from the prohibited uses or added requirements. The discretion allowed the Special Permit Granting Authority varies from general measures such as ensuring the town's water supply is protected to very specific (and sometimes numerical) measures of discharges and construction specifications.

There is little consensus on which board should be responsible for plan review and approval, special permits and enforcement. Town agencies used include the Board of Appeals, Board of Health, Board of Selectmen, Board of Water Commissioners, Building Inspector, Conservation Commission, Fire Chief and, most frequently, the Planning Board. Not many towns require more than a site plan to be submitted with the permit application. Two towns, Bourne and Littleton, also require a listing of hazardous and toxic materials and their use, septic system approval, and certification of underground storage tanks.

A summary evaluation of the uses and activities regulated follows. Although a few towns (Amherst and Norton) do not specifically address hazardous and toxic chemicals, all but one (Falmouth) prohibit their manufacture, use, storage, transportation, transmission by pipeline, disposal, dumping, discharge, etc. in the protection zones. Three towns (Bourne, Falmouth and Littleton) permit their generation by special permit. Falmouth requires a special permit for all toxic and hazardous waste uses and activities. However, cities and towns not adopting permits for hazardous waste disposal facilities prior to the passing of Massachusetts General Law c21D may not pass these permits now.

<u>Activities and Uses Regulated</u>

Oil, fuels and petroleum products are not regulated by all the towns. Several allow their sale, storage and transport by special permit and several prohibit it. Other commercial and industrial uses prohibited by one or more towns include gasoline service and repair stations, bus/truck terminals, car/truck washes, laundries, hairdressing and beauty shops.

The varying degrees of regulation of septic systems include a prohibition on all systems within the zone, prohibiting all but single family house discharges, requiring a special permit on large and industrial systems only, and allowing all systems that can meet the performance standards. Two towns (Dartmouth and Wilbraham) specifically prohibit the use of septic system cleaners which contain specified toxic chemicals.

Solid waste disposal sites, whether they be junk yards or sanitary landfills, are generally prohibited except in Littleton's water resource zone where a special permit is required. Dartmouth also prohibits animal feedlots and manure storage in the district.

Only a few towns address pesticides, herbicides and fertilizers, prohibiting their manufacture and storage in the district and requiring a special permit for large scale application.

De-icing chemical outdoor storage is prohibited by many of the towns. Some permit storage in an enclosure which meets specified performance standards. Application of NaCl (a road salt) is prohibited in some towns; others require a reduction in amounts. Three towns (Dartmouth, Littleton and Plymouth) also specifically prohibit dumping of snow from outside the district.

Sand and gravel extraction is prohibited in 4 towns. Several others set a limit of 4, 5 or 10 feet above the high water table. For road construction and drainage, the most frequently reflected concerns are with runoff being used to recharge the groundwater and the installation of oil, grease and sediment traps.

Many towns require a special permit if a large portion of the lot is to be made impervious (including roof and paving). Impervious surfaces prevent water from infiltrating through the soil and recharging the groundwater. Water is instead channelled as runoff to surface water bodies. If a large area of the aquifer recharge area is covered over, the groundwater will not be replenished. Among these towns there is little consensus as to the percentage of the lot which can be covered with impervious surfaces. The towns that were examined chose 50%, 40%, 25%, 20%, and 10%. Other variations include a limit on the number of parking spaces in a lot (Dartmouth) and requiring a special permit if less than 30% of the lot is left in the natural state (Bourne and Littleton).

Residential development is allowed by several towns if connected to a sewer or on a 40,000 ft. lot or larger. Most towns allow existing structures although enlargements often require a special permit. Agricultural uses are either allowed or are specially permitted.

Aside from solid waste disposal, towns differ on whether a use should be prohibited or allowed with a special permit. The types of zones protected also vary from a radius around a municipal well to an entire watershed feeding a reservoir or a well field. This difference in the breadth of area protected could account for the choice of a special permit requirement rather than a prohibited use. Generally, the more narrowly defined protection zones (i.e., those immediately surrounding the well zone) are more strictly regulated than the broader watershed protection zones. Furthermore, towns with more than one zone will often prohibit a use in the aquifer zone but issue a special permit in another zone. Similarly, uses requiring a special permit in the aquifer zone may be allowed in another zone.

For those towns issuing special permits for certain uses or as exemptions, criteria for granting special permits generally address the quality and quantity of the water resources. The concerns are both to perpetuate the recharge, thereby maintaining the groundwater yield, and to prevent degradation of the water quality. Some use drinking water standards and others use the current water quality as the measure.

Summary

Thus, in the adopted zoning bylaws there is much consensus. Most use overlay districts and supplementary written descriptions to identify the area. There is general agreement that hazardous and toxic materials, petroleum products, waste disposal, septic systems, excavation, construction of

impervious surfaces and, in certain communities, agricultural uses are potential sources of groundwater contamination and need to be regulated within these districts. The variation in bylaws is most evident in the specifics: whether or not to allow uses which generate hazardous wastes (as opposed to manufacture, storage, use, etc.); how much and what type of discharges to allow in septic systems; what depth above high groundwater level to allow sand and gravel extraction and which town agency should administer and/or enforce the regulations.

A second zoning approach used by a number of towns (2) has been to institute large lot zoning for water supply protection and other conservation purposes. Several of these zoning ordinances have been tested in court. A bylaw allowing only two-acre lots was upheld on the grounds of protection of public health because each lot had to have a well and septic system (3). The relationship between the bylaw and water supply was clear. In another case the court would not allow 2.5 acre zoning because the town wanted to keep the land in its natural state (4). To use large lot zoning for groundwater protection, the relationship between the bylaw and the protection of health, safety and general welfare must be clear.

Thus, both good technical information on groundwater location and flow direction in the town and a clear relationship between the bylaw provisions and water supply are essential to a strong bylaw which will hold up if tested in court.

In order to establish groundwater protection zoning a community must understand amending procedures, special permit procedures, and appeals procedures for zoning bylaws. Requirements for each of these procedures are listed below (5).

I. AMENDING PROCEDURES (ZONING BY-LAWS)

A. Submittal

1. To city council or board of selectmen.
2. By city council, board of selectmen, board of appeals, individuals owning land affected by the change, 10 registered voters for a city, 10 registered voters for a town meeting, 100 registered voters for a special town meeting, and other methods provided by municipal charter, the planning board, and regional planning agency.
3. Submittal to planning board by city council or selectmen within 14 days of receipt.

B. Public Hearing

1. Held by planning board (and city council in cities) within 65 days of receipt.

C. Vote

1. City council or town meeting must wait 21 days after hearing to receive report from planning board before city council or town meeting may vote.

2. Amendments must be voted by:
   a. 2/3 of all members of town council
   b. 2/3 of all members of city council
   c. 2/3 of town meeting
   d. 2/3 of each branch of a two branch form of government

D. Following Adoption

1. In a town, town must submit amendment to Attorney General for approval.
2. Effective date:
   a. In a city, date city council voted to adopt amendment
   b. In a town, date town meeting voted to adopt amendment provided Attorney General subsequently approves and amendment is published and/or posted
3. A copy must be sent by city or town to Department of Community Affairs.

II. SPECIAL PERMIT

A. Authorization

1. Zoning bylaw or ordinance must authorize which uses are permitted in specific districts by special permit.
2. The Special Permit Granting Authority (SPGA) shall adopt rules and regulations for the conduct of its business and relative to issuance of special permits.

B. Special Permit Granting Authority

1. May only be city council, selectmen, board of appeals, planning board, or zoning administrator.

C. Public Hearing

1. Must be held within 65 days from date SPGA receives application or city or town clerk.

D. Review

1. If zoning ordinance or bylaw provides for review of special permits by other boards or agencies 35 days from date of receipt will be allowed for recommendations.

E. Final Action

1. Shall be taken within 90 days of public hearing
2. If zoning administrator is SPGA a decision shall be issued within 35 days.
3. Upon granting special permit, SPGA shall:
   a. File a copy of the decision with planning board and city or town clerk
   b. Mail certified copy of the decision to applicant and to owner if other than applicant
   c. Send notice of decision to applicant, parties in interest, parties who requested notice

d. Within 14 days of the decision, copies of the detailed proceedings must be filed with city or town clerk.

F. Effective Date

1. When the city or town clerk certifies on a copy of the decision that either twenty days have elapsed since decision was filed without an appeal, or decision was appealed and was dismissed or denied.
2. When the certified decision has been recorded at owner's expense in the applicable registry of deeds.

III. APPEALS

A. By any person aggrieved by a decision of an SPGA whether or not previously a party to the proceedings, or any municipal officer or board.

B. Appeal to the Superior Court, District Court, or to the Housing Court of Hampden County.

C. Action must be brought within 20 days after decision is filed with city or town clerk.

3.2 <u>Local Bylaws or Ordinances</u>

M.G.L. Ch 40 gives municipalities the authority to pass local bylaws and ordinances they judge to be conducive to the municipalities' welfare. Bylaws and ordinances differ from zoning bylaws under Ch. 40A in that no public hearing is required to adopt the ordinance or bylaw, and pre-existing uses can be regulated (they are protected as non-conforming uses under Ch. 40A Section 6).

Four towns (6) have adopted general bylaws controlling hazardous and toxic materials under Ch. 40 Section 21. One (Bedford) also addresses petroleum products. The regulations not only prohibit discharges, but also regulate storage of toxic and hazardous materials. In some towns these include petroleum products, pesticides and de-icing chemicals. Three towns (Barnstable, Bedford and Yarmouth) require registration and the maintenance of an inventory for quantities exceeding a specified limit. Two of these towns, Bedford and Yarmouth, have additional more stringent regulations for a second specified quantity and for those facilities sited close to vulnerable areas. In general, product tight containers (and sometimes vaults) and security provisions are required. All require prompt spill reporting and emptying of leaking tanks.

Disposal of hazardous and toxic materials into state approved landfills and hazardous waste facilities is allowed. Road salt storage and application in accordance with the Department of Public Works snow and ice control program is generally allowed, as are septic systems in accordance with Title 5. Thus, for these activities the general bylaws are more lenient than most of the zoning bylaws discussed earlier.

The format recommended by the Cape Cod Regional Planning and Economic Development District and adopted by the Towns of Barnstable and Yarmouth lists activities presumed to generate toxic and hazardous materials unless

demonstrated otherwise. Canton, uses a different format, listing uses permitted in their well zone and prohibiting all other uses unless an exception (special permit) is granted.

In contrast with the zoning bylaws these hazardous and toxic materials bylaws are generally applied town-wide. The primary emphasis is to require certain safeguards for handling and storing materials rather than to regulate land uses. With general bylaws, pre-existing uses can be reasonably regulated since they do not have non-conforming use status as under Ch.40A. Also, there are no limitations on who may be designated to enforce and/or to issue permits.

3.3 Subdivision Regulations

Another means of managing groundwater supplies available to Massachusetts' commmunities is through subdivision regulations established under M.G.L. Ch. 41, Section 81m. Subdivision control is a means to protect the safety, convenience, and welfare of the town's inhabitants by requiring adequate provision for water, sewage, drainage, and underground utility storage in all subdivision developments, and to ensure compliance of plans with applicable bylaws and board of health regulations.

A subdivision is defined as any tract of land being divided into two or more lots which do not front on a public way. This definition applies where an access to two or more lots must be provided for the development.

When reviewing the design of a proposed subdivision, the planning board should consider the potential effects of the development on groundwater. Commonly used protective measures include appropriate design and construction standards for roads, drainage works and utilities such as:

1. Roads should be designed for winter safety to reduce road salt usage to a minimum.
2. The widths of roads should be minimized to lessen the extent of impervious surfaces.
3. Unnecessary paving and disturbance of soils over groundwater recharge areas should be avoided.
4. Natural vegetation should be retained wherever possible. Vegetation reduces the erosion potential by increasing the infiltration of rainfall into the soil.
5. Runoff from the site should not be increased due to the development.

Subdivision regulations do not provide as extensive control as zoning because they are limited to only those activities associated with the subdivision of land. However, as a first step, subdivision control allows for more control than is ordinarily realized in many communities. The following requirements must be met when subdivision control is used as a groundwater protection mechanism (5).

I. ADOPTION AND AMENDING PROCEDURES

A. Planning board proposes rules and regulations.

B. Public hearing is held.

C. Vote - Rules and regulations are adopted by concurring vote of a majority of the planning board membership.

D. Rules and regulations filed with city or town clerk and a copy certified by city or town clerk transmitted to the Register of Deeds and Recorder in Land Court.

II. PLAN SUBMITTAL

A. Determining Applicability of Subdivision Regulations
   1. Plot plans submitted by applicant to planning board and notice submitted to city or town clerk.
   2. Within 14 days the planning board decides whether or not plans are subject to subdivision control. If not, the planning board certifies that it is not a subdivision, notifying the applicant and city or town clerk of this decision.

B. Procedure for Plans Requiring Subdivision Approval

   1. Applicant submits Preliminary Plan.

      a. Applicant submits plans to planning board and board of health and files notice of submission with the city or town clerk.
      b. Within 60 days the planning board votes and notifies applicant and town or city clerk by certified mail of its decision.
      c. Definitive plans must be submitted within 7 months of Preliminary Plan to preserve zoning and subdivision exemptions.

   2. Applicant Submits Definitive Plan:

      a. Applicant submits plan to planning board and board of health and files a notice with city/town clerk.
      b. Planning board reviews plan and sends notice of public hearing.
      c. Within 45 days board of health reports in writing to planning board.
      d. Planning board holds public hearing.
      e. Planning board votes after receipt of board of health report or after 45 days without a report and within 60 days after submission of Definitive Plan.
      f. Within 60 days planning board:
         1) Files certificate of its action with town/city clerk.
         2) Sends notice of decision to applicant by registered mail.

III. APPEAL

A. Must be entered in Superior Court and notice of such appeal must be given to city/town clerk within 20 days after plannin board decision is filed with city/town clerk.

Subdivision control, though not as comprehensive as zoning, is easier to administer. Plan approval is currently required for all subdivisions. Therefore, no new procedure must be implemented. Also, through subdivision regulations the board of health is required to review all plans. This additional provision ensures greater oversight of proposed activities. (5)

3.4 Board of Health Regulations

Municipal Boards of Health have far reaching powers to protect the groundwater quality in their communities. Boards of Health can regulate under provisions of M.G.L. Ch. 111 the disposal of sanitary wastes (7), the storage and handling of fuels (8) and hazardous materials (9), and the siting of facilities such as landfills. As Chapter Two demonstrates, each of these can be significant sources of groundwater pollution.

Subsurface Sewage Disposal

Most Boards of Health use the standards in Title 5 of the State Sanitary Code to regulate the subsurface disposal of sewage. This code provides minimum standards for subsurface disposal. Some communities (7) have adopted more stringent requirements such as greater setback distances from water supplies and greater heights for leaching beds above the high groundwater table. Both Title 5 and these local ordinances can also regulate activities of septage pumpers and haulers. Thus, this authority can be used to prevent contamination of the groundwater from subsurface disposal systems.

Associated with subsurface sewage disposal regulation are septic system maintenance programs. Town meetings have authorized such programs to be administered by the Board of Health (10). Frequent pumping (every three years) of septic tanks helps to assure the proper operation of a septic system. Regular pumpout programs can make the use of highly toxic liquid septic tank cleaners unnecessary. As little as a gallon of some of these hazardous cleaners can contaminate approximately a million gallons of groundwater to unsafe drinking levels.

Underground Storage of Fuels and Chemicals

The underground storage of petroleum products has been of concern to a number of Massachusetts communities. Leaking storage tanks can contaminate large volumes of groundwater (see Figure 26). Perhaps the most well-known example of groundwater contamination from leaking underground storage tanks was in Truro. The adjacent town to Provincetown had to close down its North Truro well after it was contaminated by gasoline leaking from an underground storage tank. Water had to be brought in from outside the town and residents had to obtain their drinking water from back of trucks until a new pipeline could be constructed.

Regulations designed to prevent and control leakage to groundwater from underground fuel and chemical storage have been adopted by several communities under the authority granted by Massachusetts General Law 111, Section 31 (8). The Board of Fire Protection Regulations enforces regulations governing the underground storage of fuel and chemicals.

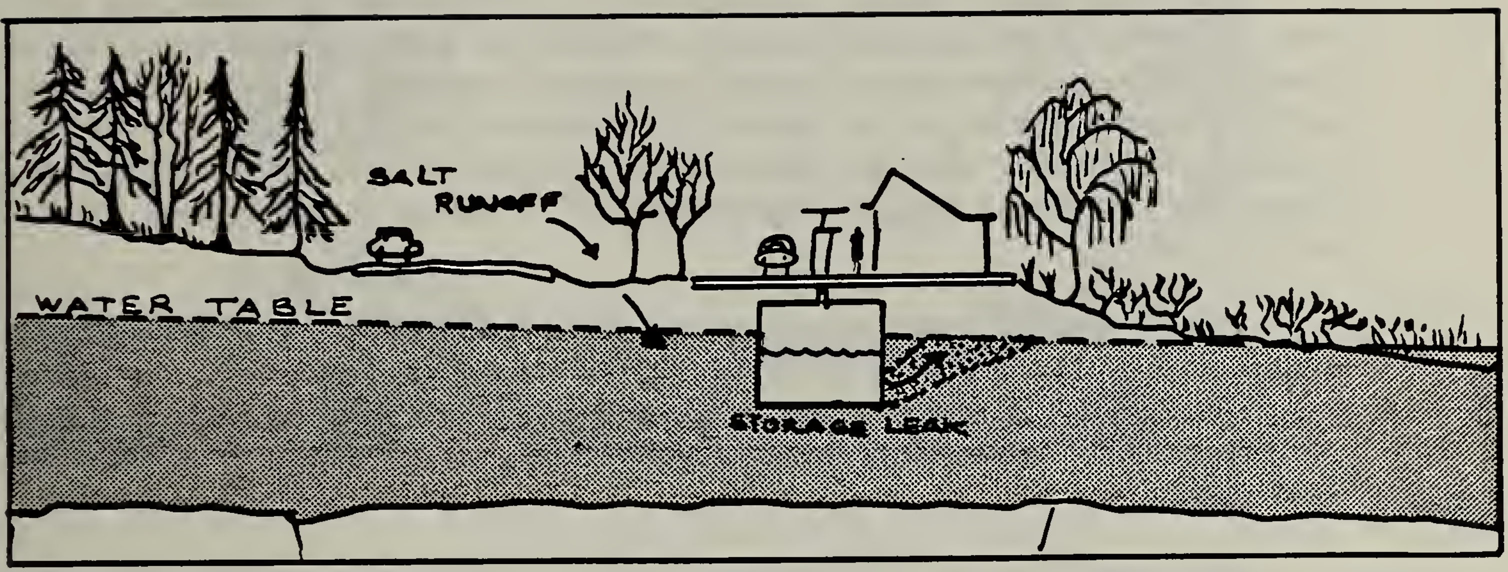


FIGURE 26. Automobile-related pollution of groundwater

A Section 31 violation carries a nominal fine; however, the real power is the town's ability to sue in equity to enforce compliance with the regulations. Water supply pollution has been upheld in court as a nuisance in which equitable relief can be sought. A claim against a regulation could succeed if the plaintiff could prove that unregulated subsurface storage of fuel does not in fact pose a threat to water supplies. A claim could succeed when there is a threat to the water supply, if the regulations under dispute do not reasonably purport to reduce that threat. In all cases brought against a Board of Health regulation, all reasonable presumptions are to be made in favor of the Board of Health.

In Dennis, the Board of Health has adopted regulations for toxic and hazardous materials under Massachusetts General Law 111, Section 31. These regulate storage and disposal of hazardous and toxic materials as well as road salts, fertilizers, pesticides and various generators of these substances.

The recently passed Hazardous Waste Siting Act, M.G.L. Chapter 21D, also places a major responsibility on the Board of Health to assist in selecting safe and reasonable sites for the treatment and disposal of hazardous materials. Many Boards of Health are being called upon to make very important decisions concerning the siting of facilities that have the potential to endanger public health and contaminate groundwater supplies.

Thus, the mandates of a Board of Health provide many methods for the protection of the public health and the environment from groundwater contamination. Septic systems, landfills, hazardous materials and other polluting and potentially dangerous wastes can now be properly managed under existing authorities by the Board of Health.

3.5 Wetlands Regulation

The Wetlands Protection Act (M.G.L. Chapter 131 Section 40) gives Conservation Commissions jurisdiction over groundwater protection. Wetland areas include wet meadows, marshes, swamps, bogs, and areas where groundwater flowing or standing provides a significant sub-strate for a plant community for at least five months of the year. Those plants or plant groups which are determinants of a wetland are named specifically in the act.

Water supply and groundwater are two of the seven recognized values named in the Wetlands Act that Conservation Commissions can reference in their actions. Often, wetlands serve as a groundwater discharge and/or recharge area depending upon the geologic conditions and the time of the year (see Figure 27).

Wetlands can be very valuable as a biological system for treating some contaminants. Certain biologically degradable contaminants when discharged upgradient from wetland areas have been broken-down as they pass through the wetlands. However, it would be a major mistake to assume that every wetland can treat wastes throughout the year; some wetlands may feed municipal or private drinking water sources during part of the year. Thus, Conservation Commissions should investigate the relationship between the town's wetlands and aquifer recharge areas before permitting discharges to a wetland.

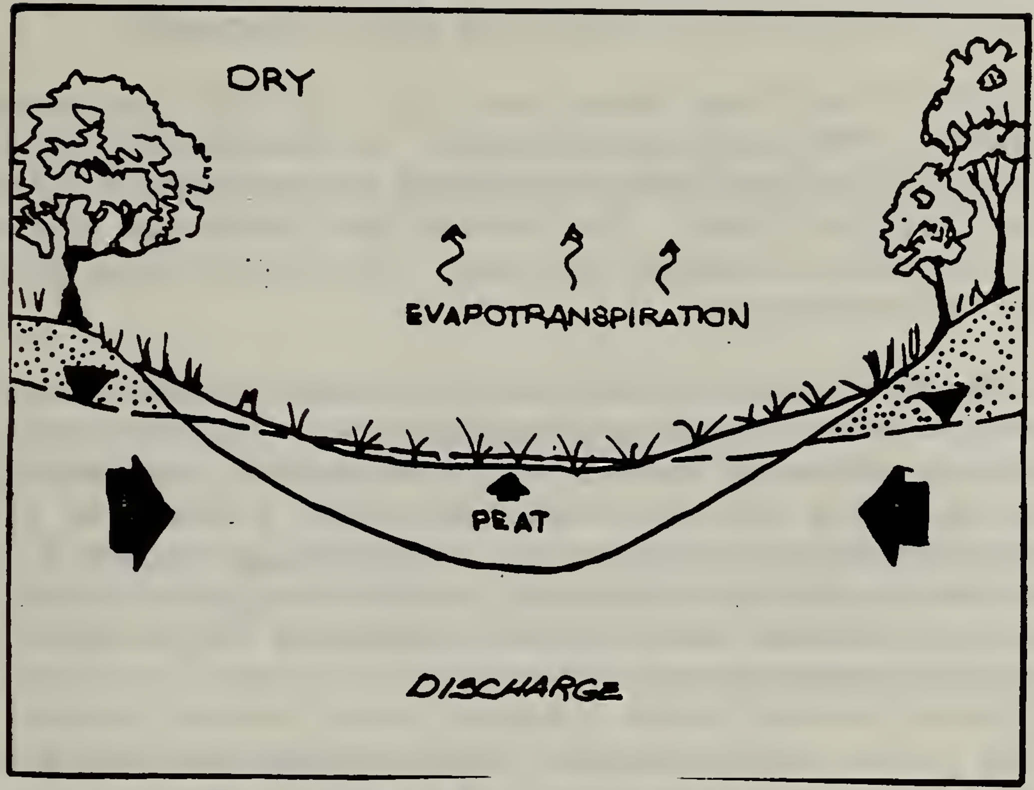
A Conservation Commission has jurisdiction over areas in a wetland or activities within 100 feet of the wetland which will affect the wetland. Proposed projects are submitted for their review and they issue an "Order of Conditions" which specifies conditions under which the proposed project may be done or denies the project in the submitted form. Often this order has provisions to protect groundwaters.

Besides the protection afforded through an order of conditions, some Conservation Commissions can have additional authorities delegated to them by local wetland zoning bylaws. Non-zoning town bylaws enacted under M.G.L. Chapter 40, Section 21 can also be used to protect wetlands and groundwaters under the direction of Conservation Commissions.

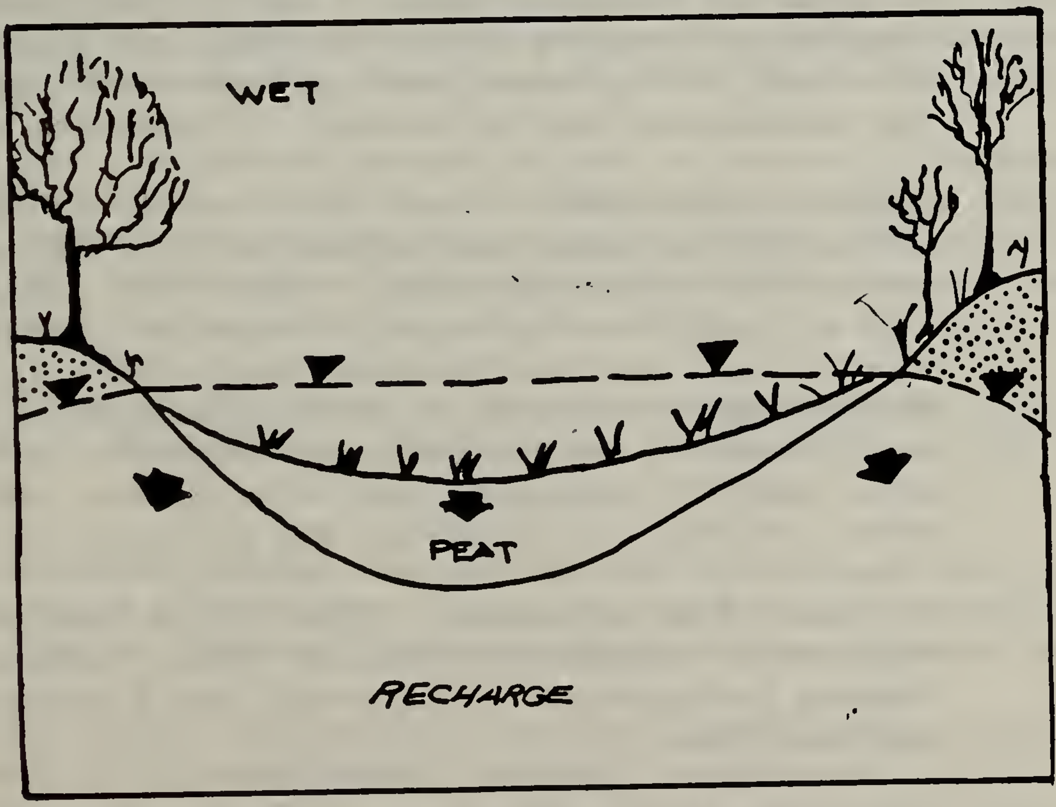
Towns are only beginning to realize the role the Wetlands Protection Act can play in the protection of groundwaters. Conditions concerning septic systems, salt storage and application, fuel storage tanks, and excavation below the groundwater table are among many items which have been included in the orders. As recharge areas are identified by hydrogeologic studies in towns, Conservation Commissions can use the Wetlands Protection Act to manage activities in those recharge areas in or adjacent to wetlands.

For more information concerning wetland regulations contact the Massachusetts Association of Conservation Commissions at the Lincoln Filene Center, Tufts University, Medford, Massachusetts 02155, (617) 628-5000, Ext. 3457.

FIGURE 27. Groundwater movement in discharge and recharge season (11).



The role of some wetlands in the groundwater system varies with the season of the year. During most of the year these wetlands serve a discharge function in two ways: (1) through evaporation from standing water surfaces, and (2) through transpiration by plants which have tapped their roots into the groundwater reservoir. The water that leaves the wetland surface through evapotranspiration is resupplied to the wetland by seepage in from the surrounding water table. The water table is usually at its lowest level during the late summer. Many wetlands in Massachusetts discharge groundwaters almost all year round.



Recharge to the groundwater zone takes place in some wetlands during times of the year when little foliage is present to discharge water through transpiration (usually spring rains and snow-melt). At times, standing water in wetlands can recharge underlying aquifers. However, most recharge occurs on surrounding uplands around wetland margins. Protection of these recharge areas is important to the protection of groundwater reservoirs and water supplies.

3.6 Local Input Into Federal and State Programs

In 1977 the Clean Water Act (P.L. 92-500) was amended to include groundwater under its jurisdiction. A section of the act prohibits the discharge of pollutants directly or indirectly without discharge permits from the State. The cities and towns are involved during the review and public hearing process. The Clean Water Act has a general mandate as follows:

> "The Aministrator (EPA) shall, after careful investigation, and in cooperation with other Federal agencies, State water pollution control agencies, and the municipalities and industries involved, prepare or develop comprehensive programs for preventing, reducing, or eliminating the pollution of the navigable waters and improving the sanitary conditions of the surface and underground waters".

The public has input to a wide variety of programs that are involved with environmental protection and cleanup. The programs listed below are the public participation programs that DEQE has to incorporate public input into it's program.

1) Division of Water Pollution Control - Construction Grants Public Participation Program. This program provides for public hearings and meetings to incorporate public input into the planning and construction of water pollution abatement facilities.

2) Division of Hazardous Wates - Public Participation Program. This program provides for public meetings and hearings and educational materials for citizens, municipalities and industries relating to the development and enforcement of hazardous waste regulations.

3) Advisory Committees. There are several advisory committees which advise the divisions and offices within DEQE as to positions and routes that should be taken. Two of the committees which provide DEQE with public, municipal, industrial, commercial and institutional input are the Hazardous Waste Advisory Committe and the DEQE/DPH Ad Hoc Committee on Health Effects. Advisory committees are formed for the building of wastewater treatment facilities, water quality management plan development, and other situations where the public's attitudes and feelings are needed.

4) Office of Public Affairs. This office handles all press releases, departmental newsletter, and all other aspects that involve releasing information to the public and directing public comments and responses.

5) Public Meetings and Hearings. The Department often holds public meetings and hearing on a wide variety of subjects in which to incorporate the input of the public. The topics discussed at these meetings and hearings range from regulation promulgation to pollution cleanup.

Footnotes and References For Chapter 3

1 The towns which have adopted zoning bylaws which protect groundwaters and recharge areas are, in alphabetical order, Amherst, Avon, Bolton, Bourne, Dartmouth, E. Bridgewater, Easton, Falmouth, Hanover, Littleton, Lunenburg, Mansfield, Marion, Needham, Norton, Plymouth, Sandwich, Townsend, Wareham and Wilbraham. Drafts are being prepared for town meeting in Attleboro, Brewster, Chatham, Fitchburg, Harwich, Leominster, Orleans, Swansea and Yarmouth. Two Regional Planning Agencies, Southeastern Regional Planning and Economic Development District and Old Colony Planning Council have prepared model zoning bylaws under Chapter 40A for groundwater/aquifer protection.

2 Towns using large lot zoning to protect groundwater include Ashby, Berlin, Groton, Harvard and Sherborn.

3 Simeone Stone Corp. v. Oliva 213 NE 2d 230 1965.

4 Aronson v. Sharon 346 Mass 598.

5 From Montachusett Regional Planning Commission (Draft) Construction Guidelines submitted to the Department of Environmental Quality Engineering in the Second Quarterly Report on the Comprehensive Watershed Protection For Wachusett Reservoir Project, August 30, 1981.

6 Towns which have adopted general bylaws to protect groundwaters under authority of M.G.L. Ch. 40 include Barnstable, Tisbury and Yarmouth. Model bylaws have been prepared by Cape Cod Regional Planning Commission, the Conservation Law Foundation and Southeastern Regional Planning and Economic Development Commission.

7 Towns adopting regulations for on-site sewage disposal under the authority of Massachusetts General Law Chapter 111 include Westminster

8 Towns which have adopted regulations for underground fuel tanks under authority of M.G.L. Chapter 111 include Barnstable, Bourne, Brewster, Dennis, Eastham, Harwich, Mashpee, Orleans, Provincetown and Truro.

9 Dennis has adopted regulations for toxic and hazardous materials under the authority of Massachusetts General Law Chapter 111.

10 For example, Barnstable and Dennis.

11 Wetlands Project, Massachusetts Audubon Society, Wetlands and the Water Cycle, 1975.

CHAPTER FOUR: STATE LAWS AND REGULATIONS GOVERNING GROUNDWATERS

Since more detailed studies of groundwater law are available (1), this chapter will only briefly describe applicable laws and regulations. First, groundwater allocation rights will be discussed in the context of other states. Then Massachusetts laws and regulations pertaining to groundwater quality will be described. This second discussion will be limited to state boards and agencies since local authorities were described in Chapter 3.

Groundwater Allocation Rights

The ownership of groundwater is viewed very differently throughout the United States. Four basic doctrines are followed: the Doctrine of Prior Appropriation; the Reasonable Use Rule; Correlative Right; and the Absolute Ownership Rule. Each doctrine reflects the physical climate of a particular state and its needs for water supply. Massachusetts uses the Absolute Ownership Rule.

1. Doctrine of Prior Appropriation

   In most of the western arid states groundwater has been considered a vital water source for many years. "First in time; first in right" is the rule in a state which follows the Prior Appropriation Rule. This system considers rights to be founded, not only on the basis of ownership of overlying land, but on the actual taking of the water.

   This system serves to protect prior interests over the rights of a new user. Thus, if an action of a new user causes a prior neighbor to lose his well, then the courts would deny the new user the right to continue water use.

   The right to use is based on obtaining a permit from the proper agency which may limit the amount of water withdrawn. That agency considers current hydrogeologic information on the movement and quality of groundwater in its decision. This system is one of the more stringent ones, but many also consider it the most equitable because an injured party can seek the courts' help in recovering the loss of what is often their only source of water supply. States which follow this rule include Utah, Alaska, Nevada and New Jersey.

2. Reasonable Use Rule

   The Reasonable Use Rule, sometimes referred to as the American Rule, relates the use of groundwater to the overlying land. A landowner is entitled to "reasonable" use of the groundwater. Reasonable uses are those which are useful and beneficial (i.e., not wasteful) relative to the specific uses or activities of that property. The transportation or diversion of water to distant lands may not be considered a reasonable use. This interpretation limits withdrawal, thus protecting neighboring wells.

3. Correlative Rights

Correlative Rights are a judicial extension of the Reasonable Use Rule to resolve groundwater disputes among landowners. The Correlative Rights Doctrine states that the rights of all overlying landowners are co-equal requiring apportionment where there is a less than sufficient supply for all reasonable users. California follows the Correlative Rights Doctrine.

The major purpose of this rule is to distribute equitable rights to the society, as a whole, from owners with large, deep wells. Deep wells could cause problems to neighboring wells under the American Rule. The Correlative Rights Doctrine serves as a check on this practice.

4. Absolute Ownership Rule

The Absolute Ownership Rule was adopted in Massachusetts in 1836. Under this rule a landowner has the unqualified right to withdraw unlimited quantities of groundwater from his land without liability to other groundwater users. The extreme nature of this rule allows a landowner to pump water to the extent of actually causing another's well to go dry. The only protection afforded by this often called "English Rule" is that the person pumping cannot act in a malicious or negligent manner. The landowner can waste the water pumped, sell the water, or use the water on lands other than where it was pumped from. This rule does not apply to the use of surface waters or to the effect of groundwater exploitation upon surface waters (1).

In Massachusetts, the law concerning surface water, the Riparian Doctrine, is different from that which applies to groundwaters. Riparian Doctrine is a system of correlative rights based on reasonable use. Each riparian owner is a landowner whose property is abutting a water body. Since the courts recognize that the movement of water is constant in surface waters, riparian rights are to protect each owner from acts of another which diminish his use or quality of the water.

The courts in Massachusetts have not yet acknowledged the hydrological fact that groundwater is in a state of movement. Without expert testimony to the contrary groundwater is treated as if it stays below a particular piece of land and does not move. However, Massachusetts does allow recovery for damage to surface water caused by excessive pumping of a neighboring landowner's well (2). No case has allowed recovery for damage to groundwater yet, but if the courts were presented with a case based upon modern scientific evidence, they might abandon the position barring recovery.

Groundwater Quality

In addition to this general case law, numerous state statutes and regulations are concerned, directly or indirectly, with the protection of groundwater, surface water and drinking water supplies.

The DEQE Division of Water Pollution Control (MGL Chapter 21 S.27) is charged to establish a program for the "prevention, control and abatement of water pollution" and the definition of water includes groundwaters. No person may discharge pollutants into waters of the Commonwealth without a permit (MGL Ch.21 Section 42). Currently, the Division has adopted several regulations under these authorities which may affect groundwaters: Rules for the Prevention and Control of Oil Pollution in the Waters of the Commonwealth (314 CMR* 6), Operation of and Maintenance of Sewerage Systems and Waste Treatment Facilities (314 CMR 7), Sewer Extension and Connection Permits (314 CMR 8) and Certification for Dredging, Dredged Material Disposal and Fill in Waters (314 CMR 9). Individual review is afforded through the permits program which is required for industrial and municipal waste treatment discharges to the ground greater than 15,000 gallons per day.

MGL C.21 Section 27(14) establishes a private right of action for any damage to the waters of the Commonwealth from any discharge of oil or hazardous materials. Any person who has been determined by the Division of Water Pollution Control to have owned or have been responsible for any spillage of oil or hazardous material is liable to any person whose property is damaged by the spillage.

Chapter 21A S.13 established the State Environmental Code (Title 5) and its associated regulations are 310 CMR 15, Minimum Requirements for the Subsurface Disposal of Sanitary Sewage. These also regulate septage disposal facilities. Subsurface disposal facilities discharging less than 15,000 gallons per day are regulated by the local Board of Health; over 15,000 gpd requires a discharge to-the-ground permit from DEQE Regional Offices and over 25,000 gpd requires an Environmental Notification Form from the State M.E.P.A. Office in the Executive Office of Environmental Affairs. In addition, any industrial discharge, irregardless of the volume, requires approval from DEQE.

The Wetlands Protection Act, Chapter 131 S.40 regulates the filling and dredging of wetlands with protection of groundwaters as one of its stated purposes. The program's regulations (310 CMR 10) are currently being revised. The relationship of wetlands to groundwater and authorities of the Conservation Commissions are discussed in Chapter Three.

Chapter 111 S.150A requires that each solid waste treatment and disposal site be assigned a site by the town or the Department. Section 150B requires that each hazardous waste facility site be assigned by the local board of health, or for State agencies by the Department after a public hearing.

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* Code of Massachusetts Regulations

Later sections of Chapter 111 address public drinking water supplies. Section 160 gives DEQE the authority to examine water supplies, make rules and regulations to prevent pollution, secure sanitary protection and ensure delivery of a fit and pure water supply to all consumers. DEQE may also delegate this authority to cities and towns. Sections 162-166 give DEQE authority to require that situations where substances are polluting underground waters be rectified. Such substances include manure, excrement, garbage, sewage or other matter that pollutes, except for ordinary methods of agriculture.

DEQE's Division of Hazardous Waste protects groundwaters from contamination under MGL C.21C (see Chapter Two's definition of disposal). The Division has also proposed Hazardous Waste Regulations (310 CMR 30). These rules for siting disposal facilities protect groundwaters from contamination by requiring detailed hydrogeologic studies and prohibiting facilities from being sited above aquifers, aquifer recharge areas or areas where groundwater flows to a drinking water supply.

Other significant state laws and regulations include MGL Ch.94B S.21C regulating hazardous substances and regulations 333 CMR 2 through 10 of the Pesticides Board. These protect public health and natural resources, including surface and ground public water supplies.

Thirteen state boards and agencies have been identified that have regulations directly or indirectly involved with the protection of groundwater, surface water and drinking water supplies. The regulations range from the plumbing code to natural resource protection programs to public safety rules about petroleum products. A list of these agencies and citations for the regulations appears in Appendix C.

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(1) Massachusetts Division of Water Resources. Groundwater and Groundwater Law in Massachusetts. Boston, MA, 1976 (republished, 1979).

CHAPTER FIVE: FEDERAL AND STATE AGENCIES PROVIDING GROUNDWATER ASSISTANCE

The following agencies can provide information, technical assistance, and direction to help communities locate, assess and protect their groundwater reserves. A summary of each's groundwater programs and/or projects follows:

Federal

U. S. Geological Survey (USGS)

Produces maps of groundwater availability, surface topography, sand and gravel deposits and bedrock deposits. The Survey also publishes special reports on individual areas and problems. A statewide aquifer mapping program is currently underway in Massachusetts and several computer programs simulating groundwater movement have been developed.

Contact Person - Michael Frimpter, Massachusetts Subdistrict Chief (617)223-2822.

U. S. Environmental Protection Agency (EPA)

EPA is the water quality regulatory agency of the federal government. The Clean Water Act, the Resource Conservation and Recovery Act, the Environmental Emergency Response Act, the National Environmental Policy Act, and the Safe Drinking Water Act charge EPA with responsibilities which affect groundwaters. In addition to preparing a groundwater protection strategy, EPA is considering designation of Cape Cod as a sole source aquifer, is assisting Massachusetts in developing a comprehensive groundwater management program, funds state hazardous waste and water pollution control programs, and funds clean-up of contaminated sites. EPA also conducts research on groundwater issues and requires Environmental Impact Statements which evaluate project impacts on groundwaters, among other issues.

Contact Person - Stephen Lathrop, Drinking Water Branch, EPA, Boston. (617)223-6688.

U. S. Department of Agriculture, Soil Conservation Service (SCS)

The SCS works through local conservation districts, with the assistance of state and other federal agencies, to conserve and improve natural resources. The SCS is involved in soils mapping, conservation planning, special studies, resource inventories (including groundwater), flood hazard analysis, and watershed management programs. Direct technical assistance is also provided to communities on soils analysis, flooding, and erosion and sedimentation control.

Contact Person - Sherman Lewis, State Conservationist (413)256-0441.

U. S. Department of the Army, Corps of Engineers

The Army Corps of Engineers is involved in many studies and projects related to flooding, water supply, energy, recreation and transportation. Many of their projects influence groundwater. The Corps of Engineers provides technical assistance to communities.

U. S. Department of the Army, Corps of Engineers

Contact Person - Max B Scheider
Colonel, Corps of Engineers
Division Engineer
New England Division
424 Trapelo Road
Waltham, MA 02154

New England Interstate Water Pollution Control Commission (NEIWPCC)

NEIWPCC has an agreement with EPA to coordinate activities in groundwater among the New England states. In addition to working on interstate groundwater programs, NEIWPCC is assisting to ensure compatibility among state programs and to make the states aware of future needs.

Contact Person - Jennie Bridge (617)436-1524

State Programs

Executive Office of Environmental Affairs (EOEA)

EOEA is the Secretariat Office within the Commonwealth that is charged with the management of air, water and land resources to assure the protection and balanced utilization of such resources. Within EOEA there is an Office of the Secretary, a Department of Environmental Quality Engineering, a Department of Environmental Management, a Department of Food and Agriculture, a Department of Fisheries, Wildlife, and Recreational Vehicles, and a Department of the Metropolitan District Commission.

Activities within the Office of the Secretary include representation of Massachusetts in Washington and New England on water policy issues, a management overview of the various departments' programs, environmental review of development impacts on groundwaters through the Massachusetts Environmental Policy Act review process (MEPA), funding town purchase of water supply protection lands through the Self-Help program and special review of projects affecting groundwater in the coastal zone.

Contact Person - Elizabeth Kline, Special Assistant to the Secretary for Water Policy (617)727-9800.

Department of Environmental Quality Engineering (DEQE)

DEQE is the Commonwealth's environmental regulatory agency. DEQE's responsibilities and authorities include: regulating drinking water quality; managing and controlling air quality; regulating activities in wetlands and waterways; preventing and controlling the pollution of air and water; controlling aquatic vegetation; monitoring shellfish and shellfish harvesting areas; regulating the disposal, storage and transportation of solid and hazardous wastes; and protecting offshore resources. DEQE is divided into eight divisions with four regional offices and a central office in Boston. The divisions include: Waterways; Wetlands; Water Supply; Water Pollution Control; Air Quality Control; Hazardous Waste; Laboratories; and Emergency Response.

DEQE's Division of Water Supply and Office of Planning and Program Management have a joint two year project to coordinate groundwater management efforts. This Community Groundwater Handbook and specialized handbooks on road salts, surface impoundments and underground injection are being prepared. Extensive mapping and a classification system will assist in siting decisions and a monitoring system will be developed. The Division of Water Supply regularly monitors groundwater water quality. In 1982, guidelines for uniform enforcement actions across the state are being prepared as well as rules and regulations for a construction grants program for water distribution systems.

Contact Person - Steve Roy
Division of Water Supply
(617)292-5653

The Division of Water Pollution Control currently is developing a groundwater program. Several groundwater discharge permits have been issued. Municipal wastewater treatment plants and other NPDES permitted discharges often discharge to lagoons or place their sludge in landfills. Polluted waterways affect adjacent waterways. The Division's research division is examining some groundwater pollution issues including Cape Cod groundwaters, estimating groundwater levels and specific studies at a chemical company and a landfill.

Contact Person - Russ Isaac, Chief, Technical Services Branch
(617)727-6983.

The Division of Hazardous Waste traces the generation and transport of hazardous waste and regulates their disposal. They have completed an open dump inventory and are revising both the landfill and the hazardous waste regulations. They have an active public education program, assess sites and conduct enforcement activities.

Contact Person - Mark Lyons, Senior Planner (617)292-5578.

Department of Environmental Management

The Division of Water Resources within DEM conducts planning and programs related to groundwater and surface water in Massachusetts. They maintain statistics on precipitation, monthly water elevation and water well logs. This Division has conducted cooperative studies with the U.S. Geological Survey for groundwater investigations. They also act as the technical staff of the Water Resources Commission and are assisting communities not on centralized systems in developing water supply plans. Other division programs include wetland restrictions and flood control.

Contact Person - Charles Kennedy, Director (617)727-3267

The Bureau of Solid Waste Disposal within DEM also plays a major role in the protection of groundwater in the Commonwealth. The Bureau is involved in the siting of resource recovery and hazardous waste facilities through the Hazardous Waste Siting Council.

Contact Person - John Shortsleeve, Director (617) 727-4293.

Metropolitan District Commission (MDC)

The MDC is the agency which plans, develops, and supplies drinking water to the metropolitan Boston area. The MDC receives most of its water from the Quabbin Reservoir in Western Massachusetts. Currently, the MDC is searching for additional sources of water which may include groundwater supplies and river diversions. Studies of abandoned wells, potential wells and the effects of sewer upgrading on groundwater are currently underway.

Contact Person - Pat Corcoran, Division of Water Supply (617)727-8880

Water Resources Commission (WRC)

The WRC acts as the coordinating agency for all departments of the Commonwealth and cooperates with the federal government and all other states in carrying out water conservation and flood prevention programs. The WRC consists of the Commissioners of the Departments of Food and Agriculture, Commerce and Development, Metropolitan District Commission, Environmental Management, Environmental Quality Engineering, Fisheries, Wildlife and Recreational Vehicles, and five public members appointed by the Governor. The WRC meets and consults on matters concerning watersheds, water systems, storage basins (both natural and artificial), and underground and surface water supplies. The needs, supplies, and resources of the Commonwealth with respect to water conservation and flood prevention are presently being studied by this body.

Contact Person - Emerson Chandler, Executive Coordinator (617)727-3267

Massachusetts Department of Public Works (MDPW)

The Department of Public Works has studied the effects of de-icing chemicals and made some modifications to their road salting practices. Present studies include an evaluation of the effect road drainage features have on groundwater, monitoring the effects of using fly ash as a highway fill and the Yarmouth interception well's effectiveness in removing sodium and chloride.

Contact Person - Justin Radlo, Chief Engineer (617)727-8186

Legislative Commission On Water Supply

The Commission acts as a liaison on water supply issues for the legislators and seeks to educate them on water supply issues. The Commission prepared a report on chemical contamination of water supplies which is currently being updated and distributes periodic memoranda on specific contaminants. A major study of groundwater law is now being prepared.

Contact Person - Lee Dane (617)722-1233

Regional Planning Agencies

Massachusetts has thirteen regional planning agencies. Figure 29 indicates the boundaries for each agency. Most of the regional planning agencies were created under Massachusetts General Law c40B which enables their creation subject to state approval. Special acts have created the

Metropolitan Area Planning Council and the Old Colony Planning Council, while others, such as Cape Cod, Franklin, Martha's Vineyard, and Nantucket, are county planning departments.

All of the regional planning agencies provide their member communities with technical assistance which in some cases includes groundwater. All of the regional planning agencies have prepared water quality management plans for their areas in conjunction with Section 208 of the Clean Water Act (P.L. 92-500).

The regional planning agencies in Massachusetts are advisory only. They do, however, perform a clearing-house function (called A-95) which reviews federal and some state activities prior to approval.

The following is a list of regional planning agencies in Massachusetts and contacts.

CONTACTS FOR MASSACHUSETTS REGIONAL PLANNING AGENCIES:

Berkshire County Regional Planning Commission Karl Hekler, Director Ten Fenn Street Pittsfield, MA 01201	(413) 442-1521
Cape Cod Reg. Planning & Economic Develop. Commission Robert E. Robes, Executive Director First District Court House Barnstable, MA 02630	(617) 362-2511 Ext. 477
Central Massachusetts Regional Planning Commission William Newton, Executive Director 340 Main Street, Suite 767 Worcester, MA 01608	(617) 756-7717 756-8042
Franklin County Department of Planning Frederick Muehl, Director Court House 425 Main Street Greenfield, MA 01301	(413) 773-3003 774-3167
Lower Pioneer Valley Regional Planning Commission Timothy W. Brennan, Planning Director 26 Central Street West Springfield, MA 01089	(413) 739-5383 781-6045
Martha's Vineyard Land and Water Commission Michael Wild, Executive Director Post Office Box 1447 Oak Bluffs, MA 02557	(617) 693-3453
Merrimack Valley Planning Commission Richard Gladstone, Executive Director 350 Main Street Haverhill, MA 01830	(617) 374-0519 374-0510

Metropolitan Area Planning Council (617) 451-2770
Jonathan G. Truslow, Executive Director
110 Tremont Street
Boston, MA 02108

Montachusett Regional Planning Commission (617) 345-7376
Mohammed H. Khan, Planning Director 345-7377
76 Summer Street, Room 202 345-2216
Fitchburg, MA 01420

Nantucket Planning & Economic Development Commission (617) 228-9625
William R. Klein, Director
Broad Street, Town and County Building
Nantucket, MA 02554

Northern Middlesex Area Commission (617) 454-8021
Joseph Hannon, Executive Director 729-9587
144 Merrimack Street
Lowell, MA 01852

Old Colony Planning Council (617) 583-1833
Daniel Crane, Executive Director
9 Belmont Street
Brockton, MA 02401

Southeastern Regional Planning and Economic Development District (617) 824-1367
Alexander Zaleski, Executive Director
25 Barnum Street
Taunton, MA 02780

Massachusetts Association of Regional Planning Agencies (617) 843-5486
Joseph M. Magaldi, Coordinator
Post Office Box 264
Braintree, MA 02184

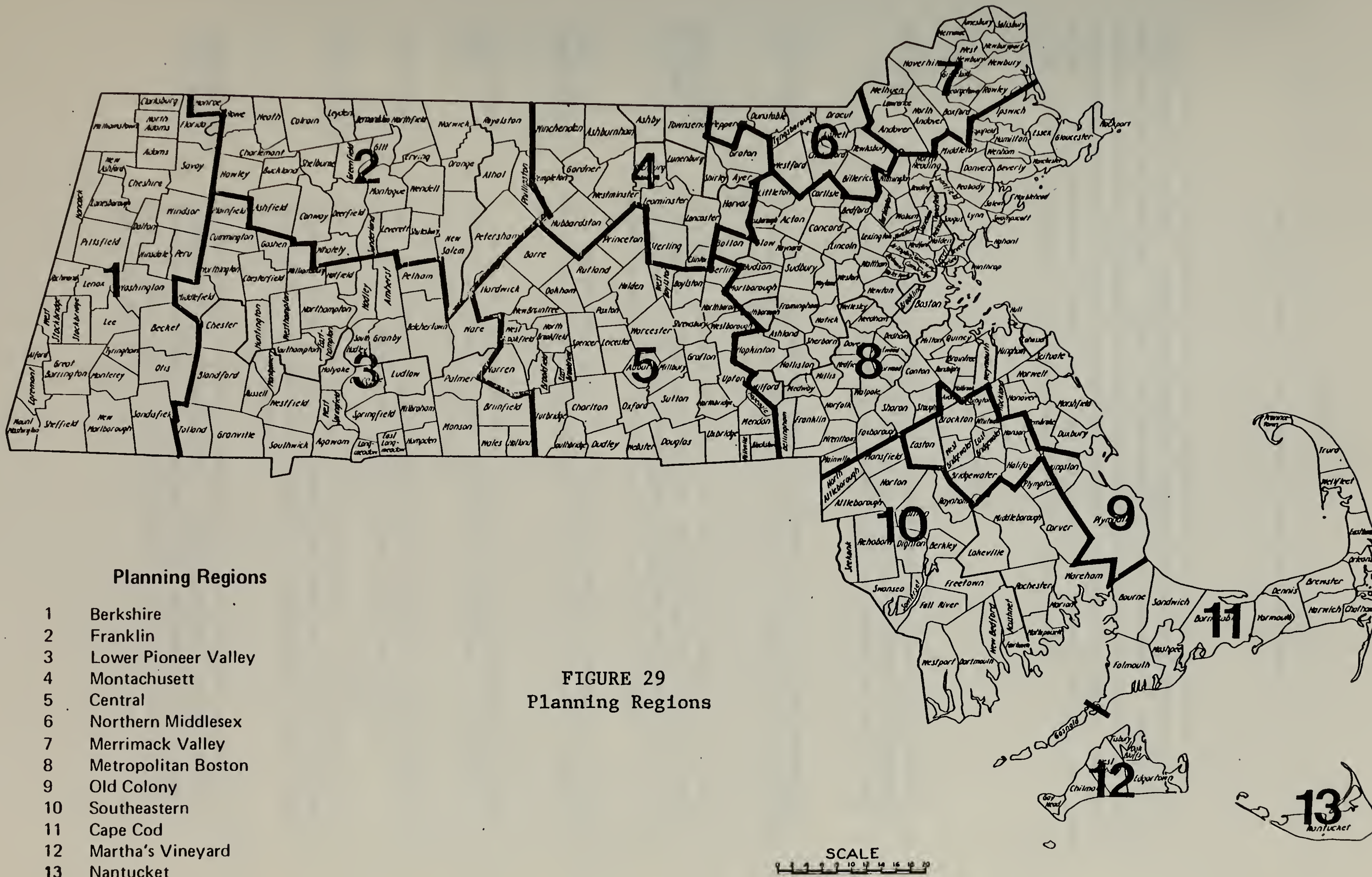

FIGURE 29
Planning Regions

APPENDIX A

Definitions of Selected Groundwater Terms

The following definitions are presented for clarification and consistency of use. Many groundwater terms can be confusing or their use can be misleading. This list should not be considered complete in any way; however, it does provide the definitions of those terms that a community is most likely to come in contact with as it begins to understand its groundwater reserves. The majority of these definitions come from the U.S. Geological Survey Water-Supply Paper 1988.

Terms

Aquifer:	A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.
Artesian:	(1) See: groundwater, confined; (2) a second meaning, as used by well drillers, refers to any well terminating in bedrock.
Capillary Fringe:	The zone immediately above the water table in which all or some of the interstices are filled with water that is under less than atmospheric pressure and that is continuous with the water below the water table.
Cone of Depression:	(Or drawdown cone): a roughly conical concavity (or dimple) in the potentiometric surface around a pumping well.
Confining Bed:	A body of "impermeable" material stratigraphically adjacent to one or more aquifers. Synonyms: aquitard; aquiclude; and aquifuge.
Diffusion:	The process by which dissolved substances move from a region of higher to one of lower concentration.
Dispersion:	The act of spreading or distributing a dissolved substance from a fixed or constant source; or the process by which a dissolved substance spreads out from a constant or fixed source.
Groundwater, Confined:	Groundwater which is under pressure significantly greater than atmospheric, and its upper limit is the bottom of a bed of distinctly lower hydraulic conductivity than that of the material in which the confined water occurs.

Groundwater, Perched: Unconfined groundwater separated from an underlying body of groundwater by an unsaturated zone. Its water table is a perched water table.

Groundwater, Unconfined: Water in an aquifer that has a water table.

Groundwater Divide: A vertical, imaginary, impermeable boundary which in an ideal, symmetrical groundwater system coincides exactly with the topographic highs which represent surface water divides from which water flows in opposite directions.

Head, Static Head: The height above a standard datum of the surface of a column of water (or other liquid) that can be supported by the static pressure at a given point. Head, when used alone, is understood to mean static head. The head is proportional to the fluid potential; therefore, the head is a measure of the potential.

Homogeneity: The quality or state of having uniform structure or composition; in hydrology, this term describes an ideal fluid.

Hydraulic Conductivity, K: If a porous medium is isotropic and the fluid is homogeneous, the hydraulic conductivity of the medium is the volume of water at the existing kinematic viscosity that will move in unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow. It can have any units of length per time suitable to the problem involved.

Hydraulic Gradient: The change in static head per unit of distance in a given direction. If not specified, the direction generally is understood to be that of the maximum rate of decrease in head.

Hydrologic Cycle: The continuous circulation of water between the ocean, atmosphere and land.

Infiltration: The entry into the soil of water made available at the ground surface, together with the associated flow away from the ground surface within the unsaturated zone.

Isotropy: That condition in which all significant properties are independent of direction.

Intrinsic Permeability: A measure of the relative ease with which a porous medium can transmit a liquid under a potential gradient. It is a property of the medium alone and is independent of the nature of the liquid and the force field causing movement.

Leachate: The liquid derived from the leaching of buried refuse in sanitary landfills and dumps by percolating water derived from rain or snowmelt. It frequently contains large numbers of inorganic contaminants, high values for total dissolved solids, and may contain many organic contaminants.

Perched Water Table: The occurrence of a discontinuous saturated zone with an unsaturated zone above and below. This condition is commonly caused by layered geologic materials with differing permeabilities.

Percolate: Water moving by gravity through pore spaces of unsaturated geologic material.

Permeability: The capacity of a porous medium for transmitting water.

Piezometer: A nonpumping well, generally of small diamter, which is used to measure the elevation of the water table or potentiometric surface. A piezometer generally has a short well screen through which water can enter.

Plume: A relatively discrete body of contaminated groundwater originating from a specified source(s) and influenced in its movement by such factors as the local groundwater flow pattern, specific gravity and solubility of the contaminant, the subsurface geology within the zone of saturation, and the influence of pumping wells.

Porosity: The ratio of the volume of small openings in soil or rock to its total volume; it is usually expressed as a percentage.

Potentiometric Surface: A surface which represents the static head. In an aquifer it is defined by the levels to which water will rise in tightly cased wells. The water table is a particular potentiometric surface.

Recharge: The entry into the saturated zone of water made available at the water table surface, together with the associated flow away from the water table within the saturated zone.

Recharge Area: That portion of a drainage basin in which the net saturated flow of groundwater is directed away from the water table.

Recharge, Artificial: The addition of water to the groundwater by activities of man at a recharge rate greater than normal.

Runoff: (1) That portion of precipitation which does not return to the atmosphere through evapotranspiration nor infiltrate the soil to recharge groundwater, but leaves the hydrologic system as streamflow; also (2), that portion of precipitation delivered to streams as overland flow to tributary channels.

Saltwater Intrusion: (Seawater intrusion): The migration of saltwater into freshwater aquifers under the influence of groundwater development (pumping).

Saturated Zone: The subsurface zone occurring below the water table where the soil pores are filled with water, and the moisture content equals the porosity.

Safe Yield: The amount of water that can be withdrawn annually from a groundwater basin without producing an undesirable result. Undesirable results include depletion of groundwater reserves, intrusion of low quality water, contravention of water rights, and others, such as depletion of streamflow and land subsidence.

Specific Capacity: The discharge from a pumping well (the pumping rate) divided by the drawdown in the well; it is a measure of the productivity of a well.

Specific Retention: The ratio of (1) the volume of water which the rock or soil, after being saturated, will retain against the pull of gravity to (2) the volume of rock or salt.

Specific Yield: The ratio of (1) volume of water which the rock or soil, after being saturated, will yield by gravity to (2) the volume of the rock or soil.

Storage Coefficient: The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. In an unconfined aquifer, the storage coefficient is equal to the specific yield.

Unconfined Aquifer: An aquifer having a water table.

Unsaturated Zone: The subsurface zone occurring above the water table and the capillary fringe where the soil pores are only partially filled with water, and the moisture content is less than the porosity.

Vertical Flow Potential: The vertical component of the hydraulic head in a three-dimensional groundwater system. The installation of two or more piezometers next to one another, each open to a different elevation, are needed to determine the vertical component of groundwater flow.

Water Table: The surface on which the fluid pressure in the pores of a porous medium is exactly atmospheric. It is the level at which water stands in a shallow well open along its length and penetrating the surficial deposits just deeply enough to encounter standing water in the bottom.

Watershed: The area of contribution to a surface water body. It is defined by topographic high points.

Appendix B

IMPLEMENTED LOCAL CONTROLS AS OF April 1, 1984

Town	Ch.40A Zoning Ordinance Bylaw	Ch.40,Sec.21 Town Bylaw	Ch.111,Sec.31 BOH Regs.	Other
ABINGTON	Floodplain & wetlands protection	Wetlands		
ALFORD				2 acre lot zoning
AMESBURY		Wetlands Floodplains Underground storage tanks		
AMHERST	Aquifer recharge & floodplain protection districts		Fuel storage Herbicide use restrictions	
ANDOVER	Floodplain protection disctrict			
ASHBY				2 acre lot zoning
ATTLEBORO		Groundwater protection		
AUBURN		Wetlands		
AVON	Watershed protection district Floodplain protection district		Fuel storage	
BARNSTABLE	Floodplain protection	Toxic & hazardous matrials Wetlands protection	Fuel storage Herbicide use restrictions	Coastal wetlands restrictions

IMPLEMENTED LOCAL CONTROLS AS OF April 1, 1984

Town	Ch.40A Zoning Ordinance Bylaw	Ch.40,Sec.21 Town Bylaw	Ch.111,Sec.31 BOH Regs.	Other
BEDFORD	Floodplain & wetlands protection district Earth removal controls	Toxic & Hazardous materials Fuel storage		
BELCHERTOWN				Road salting controls
BELLINGHAM	Earth removal controls			
BERKELEY		Fuel storage		
BERLIN	Floodplain protection district			
BLACKSTONE	Floodplain protection district			
BOLTON	Water resources & floodplain protection district			2 acre lot zoning
BOURNE	Water resources protection district	Wetlands	Fuel storage Toxic & Hazardous materials Herbicide use restrictions	Inland & coastal wetlands restrictions
BOXBOROUGH	Wetlands & watershed protection district Floodplain protection district			

IMPLEMENTED LOCAL CONTROLS AS OF April 1, 1984

Town	Ch.40A Zoning Ordinance Bylaw	Ch.40,Sec.21 Town Bylaw	Ch.111,Sec.31 BOH Regs.	Other
BOXFORD	Conservancy district			2 acre lot zoning
BOYLSTON	Watershed protection district	Earth removal Erosion & sedimentation bylaw		
BRAINTREE	Watershed protection district Floodplain & wetlands protection district			
BREWSTER	Water resource protection district Wetlands conservancy district		Fuel storage Herbicide use restrictions Ban on non-household use of pesticides	Coastal wetlands restrictions
BRIDGEWATER	Floodplain protection district			
BROCKTON	Floodplain & wetlands protection zoning ordinance			
BUCKLAND	Floodplain protection district			
BURLINGTON	Water resources & aquifer recharge zoning bylaw	Toxic & hazardous materials bylaw Earth removal bylaw		

IMPLEMENTED LOCAL CONTROLS AS OF April 1, 1984

Town	Ch.40A Zoning Ordinance Bylaw	Ch.40,Sec.21 Town Bylaw	Ch.111,Sec.31 BOH Regs.	Other
CANTON		Hazardous materials bylaw		
CARLISLE	Floodplain & wetlands protection districts			
CARVER	Wetlands & floodplain protection district Earth removal controls			
CHATHAM	Conservancy district		Fuel storage Toxic & hazardous materials Herbicide use restrictions	Coastal wetlands restrictions
CHELMSFORD	Floodplain protection district	Hazardous materials Earth removal		
CHESHIRE	Floodplain protection district			
CHILMARK	District of critical planning concern			Coastal wetlands restrictions
CLINTON	Floodplain protection Earth removal			Subdivision Regs. w/ erosion control
COHASSET				Coastal wetlands restrictions

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IMPLEMENTED LOCAL CONTROLS AS OF April 1, 1984

Town	Ch.40A Zoning Ordinance Bylaw	Ch.40,Sec.21 Town Bylaw	Ch.111,Sec.31 BOH Regs.	Other
COLRAIN	Floodplain zoning district			
CONCORD	Groundwater conservancy district Floodplain conservancy district Earth removal		Toxic & Hazardous materials	
CUMMINGTON				Road Salting controls
DANVERS	Floodplain protection district Inland floodplain & watershed protection district			
DARTMOUTH	Aquifer protection district Inland wetlands & watershed protection district Coastal wetlands & flood-prone land district Hazardous waste controls	Hazardous materials bylaw		
DEDHAM	Floodplain protection district			Inland wetlands restrictions
DENNIS		Wetlands Protection	Fuel storage Toxic & Hazard-materials Ban on septic system additives Herbicide use restrictions	Coastal wetlands restrictions

IMPLEMENTED LOCAL CONTROLS AS OF April 1, 1984

Town	Ch.40A Zoning Ordinance Bylaw	Ch.40,Sec.21 Town Bylaw	Ch.111,Sec.31 BOH Regs.	Other
DOUGLAS	Earth removal	Wetlands protection		
DOVER				Inland wetlands restrictions
DRACUT	Earth removal			
DUDLEY	Conservancy district Floodplain district			
DUXBURY	Conservation district	Wetlands protection		Coastal wetlands restrictions
E. BRIDGEWATER	Watershed protection district Floodplain & wetlands protection district	Road salting controls		
E. LONGMEADOW	Floodplain protection district			
EASTHAM		Toxic & Hazardous materials	Fuel storage Toxic & hazardous materials Herbicide use restrictions	Inland & coastal wetlands restrictions
EASTHAMPTON	Aquifer protection district			
EASTON	Groundwater protection district Floodplain protection district			

IMPLEMENTED LOCAL CONTROLS AS OF April 1, 1984

Town	Ch.40A Zoning Ordinance Bylaw	Ch.40,Sec.21 Town Bylaw	Ch.111,Sec.31 BOH Regs.	Other
EDGARTOWN	Districts of critical planning concern		Fuel storage Toxic & hazardous materials Private well regs.	Coastal wetlands restrictions
ESSEX				Coastal wetlands restrictions
FAIRHAVEN	Floodplain district			
FALMOUTH	Water resource protection district		Ban on septic system additives	Coastal wetlands restrictions
FITCHBURG	Water supply protection district			
FOXBOROUGH		Earth removal		
FRANKLIN	Floodplain protection district			
GAY HEAD				Coastal wetlands restrictions
GEORGETOWN	Floodplain protection district	Wetlands protection		Road salting controls
GOSHEN				Road salting controls
GRAFTON		Earth removal		
GRANBY	Floodplain & Wetlands protection district Earth removal			

IMPLEMENTED LOCAL CONTROLS AS OF April 1, 1984

Town	Ch.40A Zoning Ordinance Bylaw	Ch.40,Sec.21 Town Bylaw	Ch.111,Sec.31 BOH Regs.	Other
GROTON		Toxic & Hazardous materials Fuel Storage	Sewage disposal	
HADLEY	Floodplain protection district			
HAMILTON	Conservancy district			
HANOVER	Water resource protection district Floodplain & wetlands protection districts			Coastal wetlands restrictions
HANSON	Aquifer protection district			
HARVARD				1.5 & 3.0 acre lot zoning
HARWICH	Water resource protection district		Fuel storage Advanced treatment for multi-family housing Septage disposal	Coastal wetlands restrictions
HATFIELD	Floodplain protection district			
HAVERHILL	Floodplain protection district	Fuel storage Toxic & Hazardous materials		

IMPLEMENTED LOCAL CONTROLS AS OF April 1, 1984

Town	Ch.40A Zoning Ordinance Bylaw	Ch.40,Sec.21 Town Bylaw	Ch.111,Sec.31 BOH Regs.	Other
HINGHAM	Floodplain & water-shed protection district Earth removal	Wetlands protec-tion		
HOLLISTON	Aquifer protection district Wetlands & floodplain protection district			
HUDSON	Protective zoning by-law Floodplain/wetlands district	Toxic & hazardous materials		
IPSWICH	Water supply protec-tion district			Coastal wetlands restric-tions
KINGSTON	Conservancy district			
LAKEVILLE	Floodplain district Water resource protec-tion district			
LANCASTER	Floodplain protection district			
LENOX	Floodplain protection district			
LEXINGTON	Wetlands protection district Floodplain protection district	Wetlands protec-tion		

IMPLEMENTED LOCAL CONTROLS AS OF April 1, 1984

Town	Ch.40A Zoning Ordinance Bylaw	Ch.40,Sec.21 Town Bylaw	Ch.111,Sec.31 BOH Regs.	Other
LINCOLN	Wetlands & watershed protection district Floodplain Protection district			
LITTLETON	Water resource & aquifer protection district Wetlands & floodplain controls	Toxic & hazardous materials Groundwater monitoring bylaw		
LOWELL	Wetlands Protection			
LUNENBURG	Water supply protection district	Earth removal		2.0 acre lot zoning
LYNNFIELD	Floodplain protection district Earth removal			
MANSFIELD	Water supply protection district			
MARBLEHEAD	Earth removal			
MARION	Water supply protection district			Coastal wetlands restrictions
MARLBOROUGH	Floodplain & wetlands protection district			Inland wetlands restrictions
MARSHFIELD	Inland wetlands district			Coastal wetlands restrictions

IMPLEMENTED LOCAL CONTROLS AS OF April 1, 1984

Town	Ch.40A Zoning Ordinance Bylaw	Ch.40,Sec.21 Town Bylaw	Ch.111,Sec.31 BOH Regs.	Other
MASHPEE			Fuel storage Toxic & Hazardous materials	
MEDFIELD	Floodplain protection district Watershed protection district			
MEDWAY	Floodplain & wetlands protection district			
METHUEN	Floodplain district	Wetlands protection		
MIDDLEBOROUGH	Wetlands district Floodplain district			Fire Dept. regs. for underground fuel storage
MIDDLETON	Conservancy district			
MILFORD	Floodplain protection district			
MILLIS	Watershed & floodplain protection districts			Inland wetlands retrictions
NANTUCKET	Aquifer protection district Wetlands protection			Coastal wetlands restrictions Sole source aquifer designaation. Nantucket Land Bank Act

IMPLEMENTED LOCAL CONTROLS AS OF April 1, 1984

Town	Ch.40A Zoning Ordinance Bylaw	Ch.40,Sec.21 Town Bylaw	Ch.111,Sec.31 BOH Regs.	Other
NATICK	Water resource protection district			
NEEDHAM	Aquifer protection district Radioactive wastes Earth removal controls		Toxic & hazardous materials	Inland wetlands restrictions
NEWBURY	Floodplain protection district			Coastal wetlands restrictions
NEWBURYPORT	Floodplain district Earth removal controls			Coastal wetlands restrictions
NEWTON	Floodplain protection district Watershed protection district			Inland wetlands restrictions
NORFOLK	Floodplain/wetlands protection district			Inland wetlands restrictions
NORTH ANDOVER	Aquifer protection district Floodplain protection district	Fuel storage Toxic & Hazardous materials		
N. ATTLEBOROUGH	Aquifer protection district			
NORTHBOROUGH	Floodplain protection district	Wetlands protection Earth removal	Herbicide use restrictions	

IMPLEMENTED LOCAL CONTROLS AS OF April 1, 1984

Town	Ch.40A Zoning Ordinance Bylaw	Ch.40, Sec.21 Town Bylaw	Ch.111, Sec.31 BOH Regs.	Other
NORTHFIELD	Floodplain protection district			
NORTON	Floodplain & wetlands protection Earth removal bylaw			
NORWELL	Aquifer protection district Floodplain/watershed & wetlands protection district	Wetlands protection		Coastal wetlands restrictions
NORWOOD	Floodplain protection district Earth removal controls			
OAK BLUFFS	Coastal protection district	Fuel storage		Coastal wetlands restrictions
ORANGE	Hazardous waste disposal controls			
ORLEANS	Aquifer protection district Conservancy district		Fuels storage Toxic & hazardous materials Herbicide use restrictions	Inland & coastal wetlands restrictions
OTIS		Radioactive waste disposal controls		
PELHAM	Water supply protection district Earth removal controls			Road salting controls

IMPLEMENTED LOCAL CONTROLS AS OF April 1, 1984

Town	Ch.40A Zoning Ordinance Bylaw	Ch.40,Sec.21 Town Bylaw	Ch.111,Sec.31 BOH Regs.	Other
PEMBROKE	Floodplain & watershed protection district			Coastal wetlands restrictions
PHILIPSTON	Earth removal			
PLAINVILLE	Water supply protection controls-radioactive wastes Earth removal			
PLYMOUTH	Aquifer protection district Wetlands protection district Natural features conservation controls	Wetlands protection	Private well regs. Sewage disposal Herbicide use restrictions	Coastal wetlands restrictions
PLYMPTON	Floodplain & watershed protection district			
POCASSET	Water resource protection district			
PROVINCETOWN			Fuel storage	Coastal wetlands restrictions Road salting controls
QUINCY				Coastal wetlands restrictions
RANDOLPH	Watershed & wetlands protection district		Herbicide use restrictions	
RAYNHAM	Earth removal Hazardous material controls Wetlands district Floodplain protection district			

IMPLEMENTED LOCAL CONTROLS AS OF April 1, 1984

Town	Ch.40A Zoning Ordinance Bylaw	Ch.40,Sec.21 Town Bylaw	Ch.111,Sec.31 BOH Regs.	Other
READING	Wetlands protection district Floodplain protection district			
RICHMOND	Floodprone areas and wetlands district			
ROWLEY	Floodplain & water protection district	Earth removal controls		Coastal wetlands restrictions
RUTLAND	Watershed protection district			
SALISBURY	Floodplain protection district	Earth removal controls		Coastal wetlands restrictions
SANDWICH	Water resource protection bylaw Floodplain district	Wetlands protection	Fuel storage Herbicide use restrictions	Inland & coastal wetlands restrictions
SAUGUS	Floodplain protection district			
SCITUATE	Watershed & floodplain protection district Earth removal controls		Sewage disposal	
SHARON	Groundwater resources & floodplain protection district			

IMPLEMENTED LOCAL CONTROLS AS OF April 1, 1984

Town	Ch.40A Zoning Ordinance Bylaw	Ch.40,Sec.21 Town Bylaw	Ch.111,Sec.31 BOH Regs.	Other
SHELBURNE	Floodplain protection district Earth removal bylaw			
SHERBORN	Floodplain protection district Earth removal controls			
SHIRLEY		Earth removal controls		
SHREWSBURY			Sewage disposal	
SOUTH HADLEY	Floodplain protection district			
SOUTHAMPTON				Road Saltin[illegible] controls
SOUTHBOROUGH	Conservation district Floodplain protection district Hazardous material controls	Soil & erosion controls		
SOUTHWICK		Wetlands protection		
STOCKBRIDGE	Water supply, floodplain & wetlands districts			
STONEHAM	Earth removal controls			

IMPLEMENTED LOCAL CONTROLS AS OF April 1, 1984

Town	Ch.40A Zoning Ordinance Bylaw	Ch.40,Sec.21 Town Bylaw	Ch.111,Sec.31 BOH Regs.	Other
STOUGHTON	Watershed, floodplain & wetlands protection districts			
STOW	Floodplain & wetlands protection district			
SUDBURY	Floodplain protection district	Earth removal controls		
SUNDERLAND	Watershed protection district Radioactive waste controls			3.0 acre lot zoning
SUTTON	Floodplain protection district			
TEMPLETON		Earth removal		
TEWKSBURY	Wetlands & watershed conservancy district Floodplain protection district			
TISBURY	Protective bylaw	Earth removal Toxic & hazardous materials Fuel storage		Coastal wetlands restrictions
TOLLAND	Radioactive waste controls			
TOPSFIELD	Floodplain protection district			2.0 acre lot zoning

IMPLEMENTED LOCAL CONTROLS AS OF April 1, 1984

Town	Ch.40A Zoning Ordinance Bylaw	Ch.40,Sec.21 Town Bylaw	Ch.111,Sec.31 BOH Regs.	Other
TOWNSEND	Aquifer protection district Floodplain & wetlands protection district			
TRURO			Fuel storage Herbicide use restriction	Inland & coastal wetlands restrictions
TYNGSBOROUGH	Wetlands protection			
TYRINGHAM	Earth removal controls Radioactive waste disposal			
UPTON	Floodplain district			
UXBRIDGE	Floodplain district			
WALPOLE	Floodplain protection district			Inland wetlands restrictions
WALTHAM				Inland wetlands restrictions
WAREHAM	Floodplain protection district	Wetlands protection		Coastal wetlands restrictions
WARREN	Floodplain protection district			

IMPLEMENTED LOCAL CONTROLS AS OF April 1, 1984

Town	Ch.40A Zoning Ordinance Bylaw	Ch.40,Sec.21 Town Bylaw	Ch.111,Sec.31 BOH Regs.	Other
WAYLAND	Floodplain & watershed protection districts	Pesticide use restrictions	Sewage disposal	
WEBSTER	Floodplain protection district			
WELLFLEET			Fuel storage Herbicide use restriction	Coastal wetlands restrictions
WELLESLEY	Floodplain & watershed protection district			Inland wetlands restrictions
W. BOYLSTON	Floodplain protection district			
W. BRIDGEWATER	Floodplain protection district			
W. BROOKFIELD	Floodplain protection district	Radioactive waste controls		
W. NEWBURY	Floodplain protection district	Toxic & hazardous materials		
W. SPRINGFIELD	Floodplain protection district			
W. TISBURY		Fuel storage		Coastal wetlands restrictions
WESTFORD	Wetlands protection Radioactive waste controls	Groundwater protection w/hazardous materials & underground storage & well protection		

IMPLEMENTED LOCAL CONTROLS AS OF April 1, 1984

Town	Ch.40A Zoning Ordinance Bylaw	Ch.40,Sec.21 Town Bylaw	Ch.111,Sec.31 BOH Regs.	Other
WESTHAMPTON	Hazardous & radioactive waste controls			
WESTMINSTER	Floodplain & wetlands protection district		Sewage disposal	
WESTON	Wetlands & floodplain protection district			
WESTPORT				Coastal wetlands restrictions
WESTWOOD				Inland wetlands restrictions
WEYMOUTH	Floodplain protection district			
WHITMAN	Floodplain & watershed protection district			
WILBRAHAM	Groundwater protection district			
WILMINGTON	Floodplain protection district			
WINCHESTER	Floodplain protection district Conservancy district			
WINTHROP	Conservation district Hazardous waste controls			

IMPLEMENTED LOCAL CONTROLS AS OF April 1, 1984

Town	Ch.40A Zoning Ordinance Bylaw	Ch.40,Sec.21 Town Bylaw	Ch.111,Sec.31 BOH Regs.	Other
WORCESTER	Floodplain & wetlands protection district Earth removal controls			
WRENTHAM	Aquifer protection district			
YARMOUTH	Water resource protection district Wetlands conservancy district Floodplain protection district	Groundwater & surface water protection Toxic & hazardous materials		Coastal wetlands restrictions

APPENDIX C

COMMONWEALTH OF MASSACHUSETTS
REGULATIONS DIRECTLY OR INDIRECTLY INVOLVED
WITH THE PROTECTION OF GROUNDWATER, SURFACE WATER
AND DRINKING WATER SUPPLIES

AGENCY TITLE #	CHAPTER NUMBER	AGENCY*	REGULATION TITLE
105 CMR	120, 400, 611	DPH	120.8-Disposal of Radioactive Materials and Wastes 400-State Sanitary Code Water Supply, Drinking Water, Sewage Disposal,Garbage and Refuse Storage & Disposal for Correctional & Detentional Facilities, Recreational & Farm Labor Camps 611-Disposal or Discarding Containers of Poisonous Substances
248 CMR	2,4.	BSE	2-Uniform State Plumbing Code 4-General Rules
257 CMR	2.	BOC	2-Certification of Operators of Wastewater Facilities
301 CMR	10, 20, 21.	EOEA	10-Massacusetts Environmental Policy Act (MEPA) 20-establishment of coastal zone management program. 21-Coastal Zone Management Programs - Federal Consistancy programs
302 CMR	2, 3, 4, 5 6.	DEM	2-Rules for Adopting Administrative Regulations 3-Scenic and Recreational River Orders 4-Rules for Adopting Coastal Wetland Orders 5-Ocean Sanctuaries 6-Rules for Adopting Inland Wetland Orders
304 CMR	4, 5, 6, 7, 10, 11, 16.	DEM/ F&P	4-Camping & Day Use Facilities 5-Special Regulations
Pertaining			to Certain Areas 6-Recreational Trail
Facilities			7-Snow Vehicles and Off Road Vehicles

AGENCY TITLE #	CHAPTER NUMBER	AGENCY	REGULATION TITLE
			10-Administration of Chapter 61: Classification and Certificatic of Forest Lands and Forest Products 11-Forest Cutting Practices 16-Water Access
310 CMR	9, 10, 15, 18 19, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32.	DEQE	9-Administration of Waterway Licenses 10-Wetlands Protection Act 15-Minimum Requirements for the Subsurface Disposal of Sanitary Sewage 18-Installation, Operation, Maintenance of Solid Waste Transfer Stations 19-The Disposal of Solid by Sanitary Landfill 22-Drinking Water Regulations 23-Cross Connections Between Public Water Supplies and Fire and Industrial Water Supplies 24-Aquifer Land Acquistion 25-State Grants for Drinking Water Filtration Plants 26-(Identifying Sources of Lost Potable Water and for Rehabilitating Water Supply Distribution Systems. 27-Underground Water Source Protection 28-Water Supply Contamination Correction Program 29-Mineral Resources Regulations 30-Hazardous Waste Regulations 31-Water Conservation Grants Program 32-Regulations for the Land Application of Sludge an(Space
313 CMR	2, 3	WRC	2-Management Planning Regulations 3-Water Well Registration
314 CMR	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 30.	DEQE DWPC	1-Rules for the conduct of Adjudicatory Proceedings. 2-Permit Procedures. 3-Massachusetts Surface Water Discharge Permit Program 4-Surface Water Quality Standards 5-Massachusetts Groundwater Discharge Permit Program 6-Massachusetts Groundwater Quality Standards 7-Massachusetts Sewer System Extension and Connection Permit Program

AGENCY TITLE #	CHAPTER NUMBER	AGENCY	REGULATION TITLE
			8-Supplemental Requirements for for Hazardous Waste Management Facilities
			9-Certification for Dredging, Dredged Material Disposal and Filling in Waters of the Commonwealth.
			10-Construction of Collection Sewers
			11-Grants for Construction of Wastewater Treatment Facilities
			12-Operation and Maintenance of Sewer Systems and Waste Water Treatment Facilities
			30-Operation and Maintenance Standards for Industrial and Municipal Wastewater Treatment Facilities which Handle Hazardous Waste
315 CMR	2.	HWB	2-Hazardous Waste Regulations
321 CMR	7.	DEM/F&W	7-Wildlife Sanctuaries

Agency Abbreviations

CMR---Code of Massachusetts Regulations
DPH---Department of Public Health
BSE---Board of State Plumbers and Gas Fitters
BOC---Board of Certification of Operators of Wastewater Treatment Facilities
EOEA--Executive Office of Environmental Affairs
DEM---Department of Environmental Management
F&P---DEM Division of Forests and Parks
DEQE--Department of Environmental Quality Engineering
WRC---Water Resources Commission
DWPC--DEQE Division of Water Pollution Control
HWB---Hazardous Waste Board
F&W---DEM Division of Fisheries and Wildlife
PB----Pesticide Board
MDC---Department of the Metropolitan District Commission
DPS---Department of Public Safety
BFPR--Board of Fire Protection Regulations
EOTC--Executive Office of Transportation & Consturction
DPW---Department of Public Works

APPENDIX D

Massachusetts Primary Maximum Contaminant Levels In Water Provided Through Community and Non-Community Water Systems

Contaminant

Inorganic Chemicals			Maximum Contaminant Level (mg/l)[1]
Arsenic (As)			0.05
Barium (Ba)			1.
Cadmium (Cd)			0.010
Chromium (Cr+6)			0.05
Flouride (Fl-)			
	Temperature		
	Degrees Fahrenheit	Degrees Celsius	
	53.7 & Below	12.0 & Below	2.4
	53.8 to 58.3	12.1 to 14.6	2.2
	58.4 to 63.8	14.7 to 17.6	2.0
	63.9 to 70.6	17.7 to 21.4	1.8
	70.7 to 79.2	21.5 to 26.2	1.6
	79.3 to 90.5	26.3 to 32.5	1.4
Lead (Pb)			0.05
Mercury (Hg)			0.002
*Nitrate (NO3)			10.
Selenium (Se)			0.01
Silver (Ag)			0.05
*Sodium (Na)			20.

Orgainic Chemicals	
A. Chlorinated Hydrocarbons Endrin (1,2,3,4,10, 10-hexachloro 6,7-epoxy-1,4, 4a,5,6,7,8,8a-octahydro-1,4-endo, endo-5,8 - dimethano naphthalene).	0.002
Lindane (1,2,3,4,5,6-hexachoro-cyclohexane, gamma isomer).	0.004
Methoxychlor (1,1,1-Trichloro 2, 2 - bis (p-methoxyphenyl) ethane).	0.1
Toxaphene (C10H10C18-Technical chlorinated camphene, 67-69 per-cent chlorine).	0.005
B. Chlorophenoxys	
2,4 - D, (2,4-Dichlorophenoxyace-tic acid).	0.1
2,4,5-TP Silvex (2,4,5-Trichloro-phenoxypropionic acid).	0.01
C. Total Trihalomethanes (TTHM)	
Sum of the organohalogen compounds	0.10

* Maximum Contaminant Level applies to all public water systems.
1 mg/l means milligram of the contaminant per liter of water.

Turbidity

a) One turbidity unit (TU), as determined by a monthly average, except that 5 or fewer turbidity units may be allowed under certain conditions.

b) Five turbidity units based on an average for two consecutive days.

Microbiological

Maximum contaminant levels varies with the analytical technique. Number of samples taken is function of population size.

a) Membrane filter technique
The coliform bacteria count shall not exceed:
1) 1/100 ml as the arithmetic mean of all samples examined per month;
2) 4/100 ml in more than one sample when less than 20 are examined per month; or
3) 4/100 ml in more than 5% of sample when 20 or more are examined per month.

b) Fermentation tube method and 10 ml standard portions. The coliform bacteric count shall not exceed:
1) more than 10% of the portions in any month;
2) three of more portions in more than one sample when less than 20 samples are examined per month; or
3) three or more portions in more than 5% of the samples when 20 or more samples are examined per month.

c) Fermentation tube method and 100 ml standard portions. The coliform bacteria count shall not exceed:
1) more than 60% of the portions in any month,
2) 5 portions in more than one sample when less than 5 samples are examined per month; or
3) 5 portions in more than 20% of the samples when 5 or more samples are examined per month.

Radioactivity

	picocuries/liter
Combined radium-226 and radium-228	5
gross alpha particle activity (including radium-226, but excluding radon and uranium	15